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Vol. 82 JANUARY-FEBRUARY 1955 No. 1

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CONTENTS

The Effects of Ascorbic Acid on Seedling Organ Growth of Lupine and Tomato. ..... *Addison E. Lee* 1

Xanthoparmelia in North America I. The Parmelia Conspersa-Stenophylla Group. ..... *Mason E. Hale, Jr.* 9

Northwestern Himalayan Mosses. ..... *Edwin B. Bartram* 22

Cytology of the Tradescantieae. ..... *Robert P. Celarier* 30

Nucellus and Endosperm in the Seed of Lima Bean (Phaseolus Lunatus L.). ..... *Clarence Sterling* 39

Germination of the Seed of Myriophyllum Spicatum L. *Bernard C. Patten, Jr.* 50

Fiber Size in Populus Deltoides Marsh. in Relation to Lean of Trunk and Position in Trunk. *Margaret Kaeiser and Kenneth D. Stewart* 57

Torreya

A Yellow Flowered Silver-Rod. By Joseph Monachino. Field Trip Reports. Book Reviews. Note. 62

Index to American Botanical Literature. 70

Published for the Club bi-monthly
by
THE BUSINESS PRESS, INC.
N. QUEEN ST. AND McGOVERN AVE.
LANCASTER, PENNSYLVANIA

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The subscription price of the Bulletin of the Torrey Botanical Club (including Torreya), is $9.00 a year except to active members of the Club. The annual membership dues covers a year's subscription to the Bulletin.

Entered as second-class matter October 8, 1940 at the post office at Lancaster, Pa., under the Act of March 3, 1879. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in Paragraph (d-2) Section 34.40 P. L. & R. of 1948.

BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 82, NO. 1, PP. 1–8 JANUARY, 1955

THE EFFECTS OF ASCORBIC ACID ON SEEDLING ORGAN GROWTH OF LUPINE AND TOMATO

ADDISON E. LEE[1]

Went (1938) observed the growth of etiolated pea seedlings after the removal of cotyledons or roots or both and noted a marked reduction in the growth of the shoots and axillary buds following the removal of either the roots or cotyledons. The amount of leaf growth was markedly reduced when the cotyledons were removed but not when the roots alone were removed. Went postulated that these different effects resulted from the presence of hormone-like factors, "calines," involved, with auxins, in controlling growth and development of particular plant organs.

Rippel (1937) and Torrey (1952) have shown that cotyledons must be present for normal lateral root formation in pea seedlings. Torrey reported that attempts to substitute for the cotyledons by applying indoleacetic acid to the cotyledonary stumps had no effect on lateral root formation. He suggests that some substances apparently are provided by the cotyledon in the early stages of growth. In later stages the roots appear to have the capacity to synthesize these factors or derive them from the nutrient medium.

V. Hausen (1948) demonstrated that the removal of cotyledons from pea seedlings four to five days after sowing resulted in the production of inferior plants, while if ascorbic acid was added to the nutrient solution in which the peas were growing, plants comparable to normal intact plants could be grown.

The presence of ascorbic acid in various plant tissues has been studied in some detail. Bessey and King (1933) suggested that ascorbic acid is present in greatest concentrations in regions of high metabolic activity. Reid (1937) found that 80% of the ascorbic acid in the cowpea plant was located in the leaf blades and even more specifically in the mesophyll of the leaves. Reid also found high concentrations of ascorbic acid in developing ovaries of cowpea plants. Reid and Weintraub (1939) determined the ascorbic acid content of excised roots of the white moonflower and concluded that probably most of it found in the roots of intact plants was translocated, either directly from the leaves or from storage organs such as the cotyledons. Shaw and Pascoe (1949) studied the formation and distribution of ascorbic acid in the radical and cotyledon of the broad bean during its seedling development. The peak of ascorbic acid content was observed in both the

[1] The author wishes to express his appreciation to Mr. Marvin B. Edwards for technical assistance in this study.

[THE BULLETIN for November–December, 1954, (81: 489–546) was issued December 30, 1954.]

cotyledons and radicals around the eighth day. These authors suggested that ascorbic acid is synthesized in the cotyledons and transported to the radicles.

Reid (1941) showed that in the roots of cowpea seedlings the highest concentration of ascorbic acid was found in the region of cell elongation and that the amount decreased toward the regions of cell division and maturation. She suggested that the activity of ascorbic acid at the surface of the cell was related to the absorption and retention of absorbed substances. Her data were interpreted further as suggesting that accumulation of ascorbic acid precedes and possibly conditions the cell expansion. Tonzig (1950, seen in abstract only) postulated that ascorbic acid is a regulator in the plant and may act as an auxin-balancing agent.

Although ascorbic acid is known to occur in many plant tissues, more information concerning its effects on specific organs of the plant and of different plants is required for a better understanding of its activity in plant growth and development. The experiments reported here were undertaken to compare the growth of organs of intact seedlings, cotyledonless seedlings, and cotyledonless seedlings supplied with ascorbic acid. Lupine and tomato were used as test plants. In the former, the cotyledons are large and fleshy, obviously serving as storage organs, whereas in the latter, the cotyledons are thin and leaf-like and obviously function in part as photosynthetic organs.

Materials and methods. Seed of *Lupinus Hartwegii* Lindl. and *Lycopersicon esculentum* Mill., University of Texas line 103 (Yellow Plum) were sterilized in 1% bromine water and placed singly in test tubes containing 1% agar. Five to seven days after germination, the seedlings were selected for uniformity and separated in groups of ten for each experiment. In order to determine the accuracy with which the selection into such groups could be made, preliminary tests were made on three different occasions in which the plants were weighed immediately after they were sorted into the various groups. The differences in the means among the groups so selected were never greater than 2% of the largest means. Generally three groups were set up for each experiment; one group of intact seedlings and two groups of seedlings from which the cotyledons had been removed aseptically. Sterile cotton was then wrapped around the stems of the seedlings and they were transferred to test tubes containing 25 ml. of White's nutrient solution (1943). The cotton around the stems of the seedlings served as a plug for the test tube. The roots were maintained aseptically throughout the subsequent growth period while the shoots above the cotton plug were not. An ascorbic acid solution, prepared from crystalline ascorbic acid and distilled water and sterilized by filtering through a Seitz filter, was added in a concentration of 40 mg./l. to the medium of one group of

the cotyledonless seedlings. The seedlings were grown in the various nutrient solutions for a period of three weeks in the greenhouse, after which they were harvested and leaf, root, and stem weights were determined separately.

The basic experiments were performed three times with tomato and four times with lupine in order to obtain growth data, and once with both species in order to obtain seedlings under the same experimental conditions for ascorbic acid determination. Seed of both lupine and tomato were also analyzed for ascorbic acid content. These determinations were made by a procedure adapted from that given in "Methods of vitamin assay" by the Association of Vitamin Chemists (1947). Extracts of the fresh plant tissues were made with 5% HPO_3 and shaken with liquid bromine to oxidize the ascorbic acid to dehydroascorbic acid. Two per cent 2,4-dinitrophenylhydrozide solution was added to the test solution to react with the dehydro-ascorbic acid. Readings were made in a photoelectric colorimeter (green filter, 425 milimicrons). The values of ascorbic acid (ppm) were obtained from a standard curve relating per cent transmission and ascorbic acid concentration.

TABLE 1. *Average fresh weight of lupine and tomato seedling parts after three weeks growth*

	Trial	Lupine			Tomato		
		Gms. fresh weight			Gms. fresh weight		
		Leaves	Stems	Roots	Leaves	Stems	Roots
1	IS	.1712	.0592	.3355	.0825	.1882	.1061
	CR	.0480	.0544	.3520	.0495	.1106	.0462
	CR + As. A	.2003	.0627	.3149	.0879	.1917	.1558
2	IS	.1893	.0947	.3471	.1045	.2701	.1142
	CR	.1130	.0718	.3343	.0840	.1665	.1550
	CR + As. A.	.1583	.0559	.3204	.1672	.3154	.2493
3	IS	.1463	.0413	.1927	.0634	.1547	.0789
	CR	.1136	.0493	.0881	.0291	.1077	.0231
	CR + As. A.	.1435	.0497	.1141	.0837	.1600	.1283
4	IS	.1604	.0598	.1446			
	CR	.1195	.0556	.1010			
	IS + As. A	.1530	.0603	.1615			

Note: IS = Intact seedlings; CR = Cotyledons removed; As. A. = Ascorbic acid used in a concentration of 40 mg./l.

Results. Lupine:—The mean fresh weight of lupine seedling parts after three weeks growth in the various nutrients are presented in table 1. The removal of the cotyledons caused a marked reduction in subsequent leaf growth and no apparent reduction in the growth of the stem. The effect of

cotyledon removal on the growth of roots was variable. In two instances root growth was reduced but likewise in two instances there appeared to be no significant reduction. Leaf formation on cotyledonless seedlings grown in ascorbic acid medium was approximately the same as on the intact seedlings which served as a control. The addition of ascorbic acid to the medium in which intact seedlings were growing did not result in any appreciable change in the growth of any of the organs.

The ascorbic acid contents of the various lupine organs under these experimental conditions are given in table 2. The values show that the ascorbic

TABLE 2. *Ascorbic acid content of lupine and tomato seedling organs.*

Plant organ	Lupine seedlings			Tomato seedlings		
	Ascorbic acid mg./gm.			Ascorbic acid mg./gm.		
	1 wk.	2 wk.	4 wk.	1 wk.	2 wk.	4 wk.
Cotyledons						
IS	0.306	0.251	0.387	0.635	0.371	0.436
Leaves						
IS		0.626	0.568		1.17	0.682
CR		0.530	0.562		0.78	0.870
CR + As. A.		0.590	0.744		0.87	0.760
Stems						
IS	0.142	0.152	0.196	0.085	0.118	0.219
CR	0.089	0.133	0.194		0.13	0.303
CR + As. A.	0.138	0.133	0.241	0.072	0.20	0.234
Roots						
IS	0.229	0.194	0.213	0.382	1.13	0.145
CR	0.198	0.168	0.219		0.38	0.253
CR + As. A.	0.269	0.226	0.291	0.270	1.09	0.282
Times increase ascorbic acid content, seedling/seed						
IS	3	3*	10*	63	315*	1726*
CR	2	2	5		207	1226
CR + AS. A.	3	2	9	68	127	1354

* Calculated exclusive of cotyledons.

acid content of cotyledons of intact plants decreased slightly by the end of the second week, but by the end of the fourth week had increased to a level slightly higher than at the time the experiment was started. The ascorbic acid content was highest in developing leaves. Stems and roots had similar low values. There were no sharply defined differences in ascorbic acid content among the organs subjected to different treatments, although there was a tendency toward a higher content in cotyledonless seedlings supplied with ascorbic acid.

In order to determine whether or not these levels of ascorbic acid con-

tent persisted in mature plants, a single greenhouse-grown plant, approximately 90 days old, was analyzed. Ascorbic acid concentration in the organs of this plant was slightly higher, but similarly distributed compared to the concentrations obtained for the seedling organs used in the experiments.

Lupine seeds were found to contain 0.523 mg./gm. or an average of 0.016 mg./seed of ascorbic acid, an amount roughly equivalent to the highest content found in the seedling organs. The seed content was increased ten fold in four week old intact seedlings, five fold in cotyledonless seedlings, and nine fold in cotyledonless seedlings supplied with ascorbic acid (Table 2).

It was not possible to determine from these results whether or not the increased leaf production of cotyledonless seedlings was a result of ascorbic acid synthesized in the cotyledons during the early stages of seedling growth or a result of ascorbic acid which may have been stored in the cotyledons prior to germination. One experiment was carried out using excised embryos instead of one-week-old seedlings. These results are given in table 3 and indicate that removal of the cotyledons from the embryos of mature seeds resulted in a marked decrease of both leaf and root production during the subsequent growth period of the embryos and that the addition of ascorbic acid to the medium did not substitute for the presence of the cotyledons. On the contrary, there appeared to be an even greater inhibition of leaf and root growth as well as some reduction of stem growth in those cultures supplied with ascorbic acid.

TABLE 3. *Average fresh weight of excised lupine embryos after four weeks in culture*

Treatment	Gms. Fresh Weight		
	Leaves	Stems	Roots
IE	.1479	.0578	.3402
CR	.0694	.0402	.0861
CR + As. A.	.0492	.0314	.1397

Tomato:—The mean fresh weight of tomato seedling organs after three weeks growth are given in table 1. Removal of the cotyledons resulted in a decrease in the growth of leaves, stems, and in most cases, roots. The addition of ascorbic acid to the medium in which cotyledonless seedlings were grown resulted in growth of the leaves and stems, which was comparable to those observed for intact seedlings. Roots of cotyledonless plants supplied with ascorbic acid grew to a considerably greater extent than did those on intact seedlings. This effect on roots was investigated further using an established clone of excised tomato roots of the same line. The addition of ascorbic acid in the concentrations of 40 mg./l. and 20 mg./l. to the root culture medium resulted in a very marked inhibition in the length of the main axis, the number of laterals, and fresh and dry weights of the excised

roots. This inhibition was more marked in roots which had been in culture for seven days than in those which had been in culture for 28 days, but was present in the older roots.

The ascorbic acid content of organs of tomato seedlings grown under the experimental conditions is given in table 2. In general, the ascorbic acid content of the tomato seedling organs was higher than that for lupine seedling organs. The values at the end of the fourth week were lower than those at the end of the second week for leaves of intact seedlings and for cotyledonless seedlings supplied with ascorbic acid but not for the cotyledonless seedlings without an ascorbic acid supplement. The values for ascorbic acid content of the stems were fairly constant in the three treatments and showed a slight increase at the end of the fourth week. The greatest variation was exhibited by the roots. The ascorbic acid content of the roots was highest at the end of the second week and dropped at the end of the fourth week to a level similar to that at the end of the first week.

Tomato seeds were found to contain 0.025 mg./gm. or an average of 0.00005 mg./seed of ascorbic acid, an amount considerably less than that found in any of the seedling organs. This amount was increased 1726 times in four week old intact seedlings, 1226 times in cotyledonless seedlings, and 1354 times in cotyledonless seedlings supplied with ascorbic acid.

Discussion. These results confirm the experiments of other investigators (Rippel 1937, Went 1938, v. Hausen 1948, Torrey 1952) in that removal of the cotyledons resulted in a decrease in growth during the seedling stage. Specifically, the results confirm those of v. Hausen (1948) in that the addition of ascorbic acid to cotyledonless plants appears to substitute for the cotyledons in the seedling stage. These results also indicate the particular organs affected by the removal of the cotyledons. In lupine, removal of the cotyledons results in less growth of the leaves, while in tomato such removal results in less growth of the leaves, stems, and roots. The addition of ascorbic acid to the medium containing these cotyledonless seedlings results in improved growth of each of these organs comparable to or better than similar organs of intact seedlings.

While ascorbic acid may substitute for the cotyledons in lupine seedlings, this appears to be the case only after the seedlings have grown for several days. In the embryo, the cotyledons apparently must supply additional substances necessary for the subsequent growth of the plant (table 2). v. Hausen also observed the effects of ascorbic acid together with other growth substances on the growth of excised pea embryos and found that while ascorbic acid stimulated the growth of such embryos, their growth was still much less than those which had not been removed from the cotyledons.

The growth data in table 1 suggest that the ascorbic acid supplied to

the cotyledonless seedlings is utilized to the extent that apparently normal seedlings are developed. This observation is also supported by comparing the increase of seedling over seed in ascorbic acid content of the experimental and control seedlings given in table 2. A comparison of the ascorbic acid content of organs of seedlings given the different treatments indicates little difference on an mg./gm. basis. On the other hand, growth, measured in terms of fresh weight at the end of four weeks, was considerably less for certain organs of the cotyledonless seedlings when compared with those of intact seedlings or cotyledonless seedlings supplied with ascorbic acid. Obviously, a shortage of ascorbic acid can be a limiting factor in growth, but a relatively uniform concentration is maintained whether the organ in question grows a great deal or very little.

The concentrations of ascorbic acid in the four week old lupine and tomato seedling organs were similar. Average concentration calculated from table 2 of intact lupine seedlings was 0.33 mg./gm. and that of intact tomato seedlings was 0.35 mg./gm. On the other hand, the concentration of ascorbic acid in the lupine seed was markedly higher than that in the tomato seed. These data suggest that ascorbic acid synthesis proceeds much earlier in the development of lupine than in the development of tomato.

The data presented here indicate that ascorbic acid is important in all of the actively growing regions of the seedling. This is in accord with Hamner's (1949) notation that ascorbic acid seems to be present in living cells that exhibit rapid metabolic activity and appears to function in their metabolism. It also indicates that the synthesis of ascorbic acid occurs in many, perhaps all of these same actively growing regions, but in insufficient amounts to provide for optimum seedling growth. Thus certain organs, the cotyledons, apparently provide the required additional amounts for optimum growth in the seedling stage.

SUMMARY

1. Fresh weights of lupine and tomato leaves, stems, and roots were compared at the end of a four weeks culture period in the following situations: (a) intact seedlings, (b) seedlings with cotyledons removed after one week, and (c) seedlings with cotyledons removed after one week and supplied with 40 mg./l. ascorbic acid.

2. Determinations of ascorbic acid content were made of seedling organs at different periods. Analyses were also made to determine the ascorbic acid content of lupine and tomato seed.

3. Removal of the cotyledons resulted in decreased growth of lupine leaves and tomato roots, stems, and leaves when compared to the growth of similar organs on intact seedlings. Equivalent or better growth of all seedling organs of both lupine and tomato were obtained when the cotyle-

donless seedlings were supplied with ascorbic acid. The data are interpreted to indicate that much of the ascorbic acid required for seedling growth is supplied by the cotyledons.

4. Ascorbic acid content was higher in leaves than in the other seedling organs. It was found in similar concentrations in both lupine and tomato organs at the end of four weeks. A somewhat uniform level of ascorbic acid concentration was found in a given organ regardless of its treatment or amount of growth. Thus a shortage appeared to limit growth but did not reduce the concentration present in organs showing sub-optimum growth.

5. The ascorbic acid content of lupine seed was considerably higher than that of tomato seed. Thus the synthesis of ascorbic acid proceeds earlier in the development of lupine than in the development of tomato.

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THE CLAYTON FOUNDATION FOR RESEARCH

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BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 82, NO. 1, PP. 9–21 JANUARY, 1955

XANTHOPARMELIA IN NORTH AMERICA I. THE PARMELIA CONSPERSA-STENOPHYLLA GROUP

MASON E. HALE, JR.

The common rock lichens of the *Parmelia conspersa-stenophylla* group have been insufficiently circumscribed in North America. There has been little agreement on the taxonomic importance of certain morphological characters, especially type of adnation of the thallus and presence of isidia, and the extent and significance of chemical variation. In this investigation three principal objectives were formulated: 1. to establish the range of variation for selected morphological and chemical characters from an analysis of a large sample of herbarium specimens and where possible also from field studies; 2. to analyse statistically the correlation between morphological characters and between such characters and the chemical constituents; and 3. to propose a reasonable disposition of the taxonomic entities and to examine their geographical distribution.

During the study 1180 packets of the *P. conspersa-stenophylla* group were examined critically. Duplicate collections from identical localities accounted for 288 of these packets, leaving a net total of 892 collections, a number which will be used in the computations. This sample size is assumed to be adequate and includes equitable representation of nearly all of North America. Specimens from the following institutions were annotated: Universities of California, Cincinnati, Colorado, Illinois, Michigan, Minnesota, West Virginia, Wisconsin, Yale University, Wellesley College, Farlow Herbarium, Smithsonian Institution, Missouri Botanical Garden, and the U. S. Department of Agriculture.

Morphology. The chief asset of mass sampling is that the frequencies of various characters are determined with greater accuracy than otherwise possible. Many specimens are randomly selected from a population and certain characters studied systematically. The rapid recording of the characters should ideally require simple decisions such as those of a presence or absence nature. Color gradations of the thallus undersurface, which in this group range from light buff to black, would be difficult to classify and likewise careful measurements or anatomical studies would usually be too time-consuming. The taxonomy of the *P. conspersa-stenophylla* group has been based traditionally on the presence of several key characters with little regard to their actual size or development. Those finally chosen as being both adaptable to mass sampling and suitable for taxonomic purposes included the following: adnation (adnate or loose) and the presence

of apothecia, isidia, secondary laciniae, and pycnidia. Only the first, degree of adnation, necessitated a subjective decision that could be made in 93.5 per cent of the cases; the remaining 6.5 per cent could not be definitely classified because of the fragmentary nature of some herbarium material. The percentage of the 892 specimens with each of the six morphological attributes is given in table 1.

TABLE 1. *Percentage of the 892 specimens with each of six morphological characteristics.*

Adnate	52.4
Loose	41.1
With pycnidia	79.6
With apothecia	64.1
With laciniae	63.9
With isidia	28.0

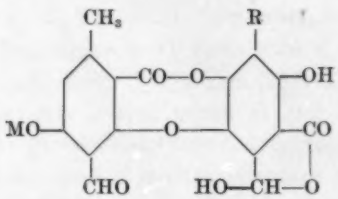
Pycnidia are highly characteristic of North American material and occur abundantly on most thalli. Secondary laciniae in all stages of development and apothecia are also commonly present, while isidia occur in least frequency. The vegetative development and numbers of apothecia, laciniae, isidia, and pycnidia varied considerably of course, but no further quantitative observations were made. About half of the material is adnate, and in fact much of it was collected attached to the rock substratum. The slightly less frequent loose material was usually collected free of the substratum. Adnate thalli tend to have short rounded lobes whereas loose specimens often have laciniate narrow lobes. The nature of the lobation was sometimes utilized to classify a thallus as adnate or loose when the absolute manner of adnation was indefinite.

Correlation of morphological characters. Any thallus, adnate or loose, may have apothecia, isidia, secondary laciniae, and pycnidia or any lesser combination of them. The significance of the statistical association of all possible paired combinations of the six characters was analysed with Chi-square. It was found that apothecia, laciniae, and pycnidia are not associated with themselves, type of adnation, or presence of isidia. In other words they are distributed at random in the North American population. There was highly significant association, however, between adnation and presence of isidia: adnate thalli have isidia far more frequently than expected and loose thalli have isidia far less frequently. The statistical manipulations appear to establish degree of adnation and presence of isidia as the statistically most important morphological characters. All theoretical combinations have been found in the population with the following frequencies:

Adnate-with isidia	22.6%
Adnate-no isidia	29.8%
Loose-with isidia	4.9%
Loose-no isidia	36.2%

Chemical constituents. The chemistry of the *P. conspersa-stenophylla* group has been investigated carefully by a number of workers and several lichen substances have been demonstrated. Usnic acid has long been known to produce the characteristic yellow color of the thallus. The presence of salacinic acid was apparently first proved by Zopf (1897) and later confirmed by Kušan (1932), Asahina (1949), and Krog (1951), among others, in material commonly referred to *P. stenophylla*. In 1937 Mohan, Keane and Nolan reported stictic acid in specimens of *P. conspersa*. Asahina (1949) confirmed the existence of that acid, as did Krog, who found with it norstictic acid, identified as Asahina's alleged α-methylethersalacinic acid which is norstictic acid with impurities (Asahina 1951). Krog also found atronorne as a constituent of *P. conspersa* in Scandinavia. Specimens colorless with KOH are known to contain fumarprotocetraric acid (Asahina 1949). Previous workers thus have demonstrated five substances besides omnipresent usnic acid in this group: atronorine, fumarprotocetraric, norstictic, salacinic, and stictic acids.

The chemical relationships of these acids are interesting. Norstictic, salacinic, and stictic acids are β-orcinol depsidones with the following skeleton:



Norstictic and salacinic acids have a hydroxyl group ortho to the aldehyde (M = H) but differ in degree of oxidation (R = CH_3 in norstictic, CH_2OH in salacinic). Stictic acid differs from norstictic only in that the ortho position is methylated (M = CH_3), allegedly preventing the formation of an insoluble complex with KOH (Mors 1952). Fumarprotocetraric acid has a very similar skeleton, lacking however the lactol ring and having a five carbon chain at R. The strictly accessory substance atronorine is a β-orcinol depside. The similarity of the main acid constituents certainly indicates that members of this lichen group have closely related metabolism. Microchemical extractions offer the only precise means of detecting these colorless substances in the lichen thalli. A macroscopic color test with KOH would lead to untrustworthy results since two acids, norstictic and salacinic, both form red though microscopically distingishable crystals and atronorine and stictic acid produce a yellow coloration with KOH. Because all the substances except usnic acid have an aldehyde group, they form distinctive crystalline condensation products with several aromatic amines,

the most suitable of which proved to be o-toluidine (G. A. o-T. of Asahina 1937 and Evans 1943). The use of a single reagent made possible the mass study of acid content of 1180 packets within a reasonable time limit. Apparently the presence of any one acid does not prevent crystallization of a second acid in the same residue.

The percentage of the specimens containing the various acids is shown in table 2. Three common acids, fumarprotocetraric, salacinic, and stictic,

TABLE 2. *Percentage of the 892 specimens with each of eight chemical constituents*

Usnic acid	100
Stictic acid	54.5
Salacinic acid	40.5
Norstictic acid	35.0
Fumarprotocetraric acid	4.4
Atronorine	1.8
Only usnic acid	.3
Unknown 1	.1
Unknown 2	.2

were never found together or in any combination of two, at least with standard microchemical methods. Norstictic acid occurred in 68 per cent of the thalli containing stictic acid and as the main component with usnic acid in only two specimens. Since norstictic acid is sometimes difficult to crystallize in low concentration with G. A. o-T., it probably went unnoticed in some specimens with stictic acid. It is suggested that norstictic acid is an accessory substance (Asahina 1939) occurring with stictic acid frequently, as it so often does in other lichen genera, for example *Lobaria* and *Stereocaulon*. Atronorine is another accessory substance which is very rare in North American material of this lichen group, having a frequency of 1.9 per cent in specimens containing either stictic or salacinic acids. It was not found with fumarprotocetraric acid or in the two specimens with only norstictic acid. Since the frequency of atronorine is so low, there was little chance that it would be found in the small sample of specimens with these two minor acids. The two types of unknown crystals could not be further investigated because of the paucity of herbarium material, and three collections contained only usnic acid. Usnic acid is confined to the upper cortex of the lichens in this group. A macrochemical extraction by Prof. Asahina gave the abundance of this acid as about 1 per cent of dry weight of the thallus for Wisconsin material (*in litt.*). The other acids are distributed chiefly in the medulla where Asahina reported about 4 per cent stictic and 6 per cent salacinic in Wisconsin specimens.

Although any one thallus may contain from one (usnic) to four (atronorine, norstictic, stictic, usnic) acids, there is no association between the major components except for norstictic and stictic acids. Any thallus with stictic acid will not produce salacinic or fumarprotocetraric acids, etc., at least as far as could be determined with the methods at hand. The popula-

tion consequently falls into three major groups, each characterized by a different acid, viz. fumarprotocetraric (4.4% frequency), salacinic (40.5%), and stictic (54.5%).

Correlation of chemical and morphological characters. The interrelation of chemical and morphological characters is a problem of major interest in lichenology. The pigmented lichen substances have long been relied on as species criteria. Red rhodocladonic acid in the apothecia is employed without hesitation to differentiate the section *Cocciferae* from *Ochroleucae* in the genus *Cladonia*. A number of lichens, however, which are morphologically similar, contain different, usually colorless substances. There is a growing tendency and a definite need to recognize the taxonomic significance of these substances whether they are evoked to make new species or recorded by other means.

Statistical association between the six morphological characters and the three disassociated acids was analysed with Chi-square (table 3). It

TABLE 3. *Matrix of significance levels for Chi-square values between three unassociated acids and adnation and presence of four morphological characters. A single plus or minus sign indicates that the value was statistically significant at the 5% level of significance, a double plus or minus at the 1% level. A blank indicates no statistical association.*

	Adnate	Isidia	Apothecia	Laciniae	Pycnidia	Loose
Salacinic acid	−−	−−				++
Stictic acid	++	++				−−
Fumarprotocetraric acid	++	++		−		−−

should be realized that the data for fumarprotocetraric acid are not strictly comparable with those for the other acids because of the disproportionately small sample size (39 specimens). The acids are not significantly associated with the characters apothecia, laciniae, or pycnidia. The production of isidia and type of adnation however are both significantly correlated with the biochemical activities of the lichens. The adnate thalli contain stictic acid far more frequently than we would expect; loose thalli have salacinic with significant positive association. Isidia occur far in excess of expected frequency in specimens that have stictic acid. Fumarprotocetraric acid, which was not found in loose thalli, occurs with positive association in adnate thalli and with isidia. It is quite significant furthermore that loose isidiose thalli produce only stictic acid (and accessory norstictic) while loose thalli without isidia most frequently produce salacinic acid. The Chi-square value in table 3 between presence of isidia and salacinic acid therefore arises solely from cases of adnate thalli.

The chemical evidence reaffirms to some extent the validity of the combinations already erected from morphological evidence: adnate-no isidia, adnate-with isidia, loose-no isidia, and loose-with isidia. All of these, excluding the last, occur in combinations with a positively associated and

with a negatively associated constituent. To this scheme, at least for adnate thalli, we may add fumarprotocetraric acid as an alternative minor acid. It is entirely possible that examination of 1000 additional packets would turn up the missing theoretical combinations; their frequency would be exceedingly small.

Taxonomic treatment. In the writer's opinion the four basic morphological combinations may be regarded as species. The chemical variants are then recorded as chemical strains (Lamb 1951, Hale 1952). If each chemical strain were uniformly elevated to specific rank, the number of such species would be limited only by our ability to detect new chemical constituents in the group. Although such a procedure would be scientific and take sound precedent from pathologic mycology, the writer hesitates to adopt it until further studies of chemical variation in lichens are undertaken. The tentative nomenclature, derived from an analysis of original descriptions and the present-day concepts of the group, is summarized below. All of the entities contain usnic acid.

Adnate-no isidia: *Parmelia conspersa* (Ehrh.) Ach. Meth. Lich. 205. 1803. Syn. *Lichen conspersus* Ehrh. in litt. apud Acharius Lich. Prod. 118. 1798.

Ch. str. 1 (Stictic acid or typical strain. Accessory substances atronorine and/or norstictic acid).

Ch. str. 2 (Salacinic acid strain. Accessory substance atronorine).

Ch. str. 3 (Fumarprotocetraric acid or "*subconspersa*" strain). Syn. *P. subconspersa* Nyl. Flora 52: 293. 1869.

Ch. str. 4 (Norstictic acid strain).

Ch. str. 5 (Usnic acid strain).

Ch. str. 6 (Acid content undetermined).

Adnate-with isidia: *Parmelia isidiata* (Anzi) Gyel. Magyar Bot. Lapok 29: 31. 1930. Syn. *Imbricaria conspersa* var. *isidiata* Anzi Cat. Lich. Sondr. 28. 1860 (non vidi). *P. conspersa* var. *isidiosa* Nyl. Flora 64: 450. 1881.

Ch. str. 1 (Stictic acid or "*lusitana*" strain. Accessory substances atronorine and/or norstictic acid). Syn. *P. lusitana* Nyl. Flora 64: 450. 1881.

Ch. str. 2 (Salacinic acid strain. Accessory substance atronorine).

Ch. str. 3 (Fumarprotocetraric acid or "*linkolae*" strain). Syn. *P. linkolae* Gyel. Magyar Bot. Lapok 28: 60. 1929.

Loose-no isidia: *Parmelia stenophylla* (Ach.) Heug. Corresp. Naturf. Verein Riga 8: 109. 1855 (non vidi). Syn. *P. conspersa* var. *stenophylla* Ach. Meth. Lich. 206. 1803.

Ch. str. 1 (Salacinic acid or typical strain. Accessory substance atronorine).

Ch. str. 2 (Stictic acid strain. Accessory substances atronorine and/or norstictic acid).

Loose-with isidia: *Parmelia isidiosa* (Müll. Arg.) Hale, nov. comb. Syn. *P. conspersa* var. *stenophylla* f. *isidiosa* Müll. Arg. Hedwigia 31: 193. 1892. *P. isidiata* f. *lacinulata* Gyel. Magyar Bot. Lapok 28: 31. 1930.

Ch. str. 1 (Stictic acid or typical strain. Accessory substance norstictic acid).

The above treatment differs in one or more respects from any other known to the writer. A number of lichenologists, for example, including Hillmann (1936), Kušan (1932), and Maas Geesteranus (1947), have adopted a highly conservative nomenclature, recognizing one species, *P. conspersa,* with numerous subspecific entities, as var. *stenophylla* or var. *isidiata.* The Scandinavian school (Lynge 1921, Krog 1951) consistently recognizes two species differing chiefly in type of adnation: *P. conspersa* (including var. *isidiata*), adnate, and *P. stenophylla,* loose. Gyelnik (1931) followed a very different path in assigning specific rank to presence of isidia, color of the undersurface, and chemical reactions with KOH and hypochlorite. His prolific research produced a very large number of species for the group with nearly 20 known from North America. The present writer finally despaired of attempts to understand his entities and their intricate and confused synonomy either in the literature or in herbaria. Color of the undersurface is a most difficult character to classify accurately, and Gyelnik's chemical tests are highly suspect since he was able to elicit different color reactions from specimens with identical chemical content. His reliance (1931) on isidia appears however to have been well conceived. Asahina (1949) has emphasized chemical differences exclusively and recognizes three species: *P. conspersa* (containing salacinic acid), *P. subconspersa* (fumarprotocetraric acid), and *P. lusitana* (stictic acid). The second of these species, it will be noted, was designated as a chemical strain in this study.

Geographical distribution. A more complete understanding of the taxonomic entities and some degree of confirmation of their validity may be gained by examining their geographical distribution over North America, as determined by herbarium and field studies. The sample size of most species is large enough to draw conclusions with some confidence.

P. conspersa occurs over most of temperate North America. Collections from 265 localities were examined. The most frequent chemical strain is stictic acid (fig. 1); salacinic (fig. 2) and fumarprotocetraric acid (fig. 3) strains have considerably less importance. All of the strains appear to have a definite pattern of distribution. In order to analyse more closely these patterns, we may divide North America into two phytogeographical regions at approximately the 90th meridian. *P. conspersa* localities are equally divided on either side of this line. The relative frequencies of the acids in the collections are shown below:

	West	East
salacinic	38%	8%
stictic	46%	92%
fumarprotocetraric	14%	0%
other	2%	0%

Stictic acid is highly characteristic of the eastern region while fumarprotocetraric and salacinic acids make up about half of the collections in the west. These and the following percentages derived from herbarium material are probably highly reliable since the collectors did not determine beforehand what acids were in the specimens. Thalli with norstictic acid only were found in Montana and Wisconsin; equally rare material of the usnic acid strain was collected in Colorado and Wyoming.

P. isidiata is represented at 202 localities of which 75 per cent are east of the 90th meridian. It is especially abundant in the northern Appalachian Mountains where it is the most common rock lichen. The acid components have very distinct distributions:

	West	East
salacinic	54%	1%
stictic	17%	93%
fumarprotocetraric	27%	5%
other	2%	1%

The stictic acid strain is once again highly characteristic of eastern North America (fig. 4) where salacinic and fumarprotocetraric acid strains (fig. 5) are virtually unknown. In the west however the two rarer strains account for 81 per cent of the collections. In the Driftless Area of Wisconsin thalli with fumarprotocetraric acid have a frequency of less than 10 per cent in random mass collections of isidiate material. Another mass survey of adnate isidiose thalli in northern Colorado gave the following percentage distributions of acids: salacinic 57%, stictic 33%, and fumarprotocetraric 10%. An extensive survey of 33 localities in New England produced stictic acid in all adnate isidiose specimens.

P. stenophylla is known from 323 localities equally distributed in eastern and western North America. Its northern limit lies in the Yukon, the southern in central Mexico. Specimens with salacinic acid (fig. 6) make up 79 per cent of the collections in each region and those with stictic acid (fig. 7) 21 per cent.

P. isidiosa, finally, has nearly complete restriction to eastern, particularly southeastern North America (fig. 8). In Wisconsin it is found only in the Driftless Area in spite of intensive exploration of the rest of the state.

Although adnate and loose thalli are distributed relatively evenly throughout North America, isidiose thalli are strongly confined to the eastern half of the continent, and when isidia occur westward the acid component changes. The chemical strains of all four species have more or less restricted geographical distributions, much as was discovered for the strains of *Rinodina oreina* (Hale 1952). The geographical evidence lends strong support for assigning taxonomic importance to presence of isidia, type of adnation, and chemical variation.

SUMMARY

1. 1180 packets of the *Parmelia conspersa-stenophylla* lichen group from 892 localities in North America were examined for type of adnation, presence of apothecia, isidia, secondary laciniae, and pycnidia, and for chemical constituents.

2. Statistical analyses indicated significant association between adnate thalli and presence of isidia. Stictic acid was significantly associated with both adnate thalli and presence of isidia, salacinic with loose thalli. Apothecia, secondary laciniae, and pycnidia were not associated with any characters.

3. The basic morphological combinations were recognized as distinct species as follows: adnate-no isidia: *P. conspersa* (Ehrh.) Ach; adnate-with isidia: *P. isidiata* (Anzi) Gyel.; loose-no isidia: *P. stenophylla* (Ach.) Heug.; and loose-with isidia: *P. isidiosa* (Müll. Arg.) Hale, nov. comb. Each species exists as one to six chemical strains, most of which have definite geographical distributions.

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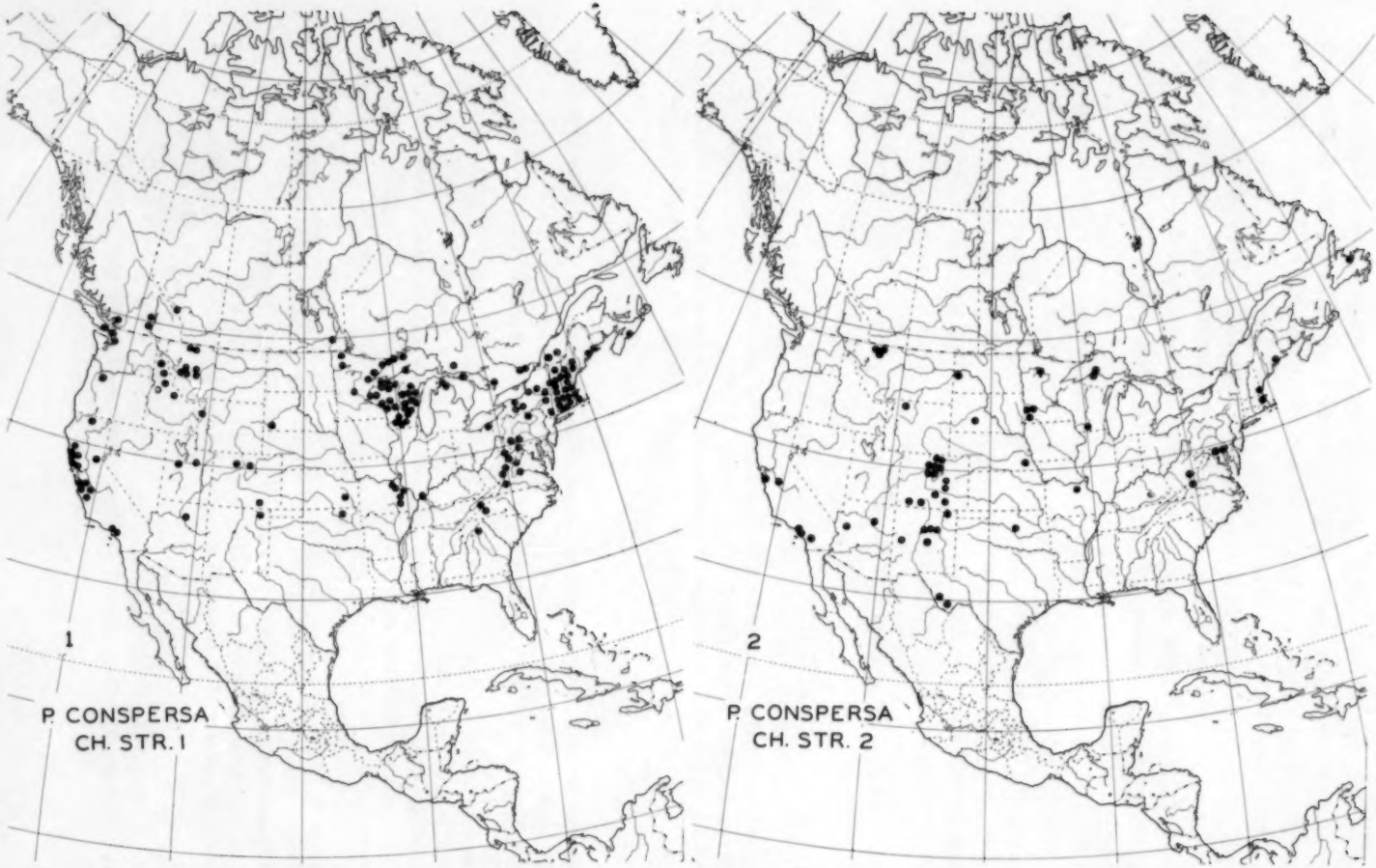


FIGS. 1–4. Geographical distributions of members of the *P. conspersa-stenophylla* group in North America. FIG. 1. *P. conspersa* Ch. str. 1 (Stictic acid). FIG. 2. *P. conspersa* Ch. str. 2 (Salacinic acid).

FIGS. 1–4. Geographical distributions of members of the *P. conspersa-stenophylla* group in North America. FIG. 1. *P. conspersa* Ch. str. 1 (Stictic acid). FIG. 2. *P. conspersa* Ch. str. 2 (Salacinic acid).

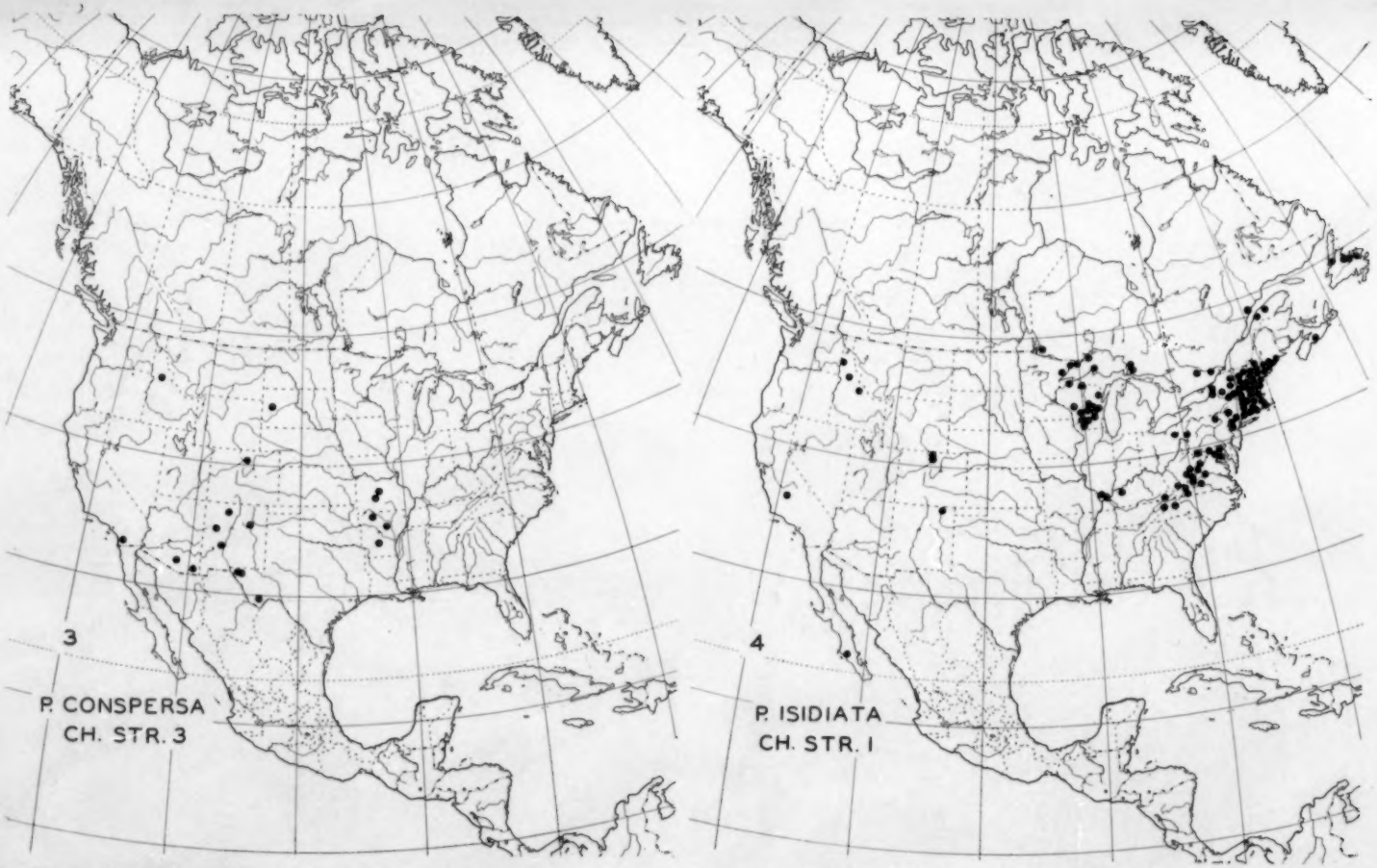
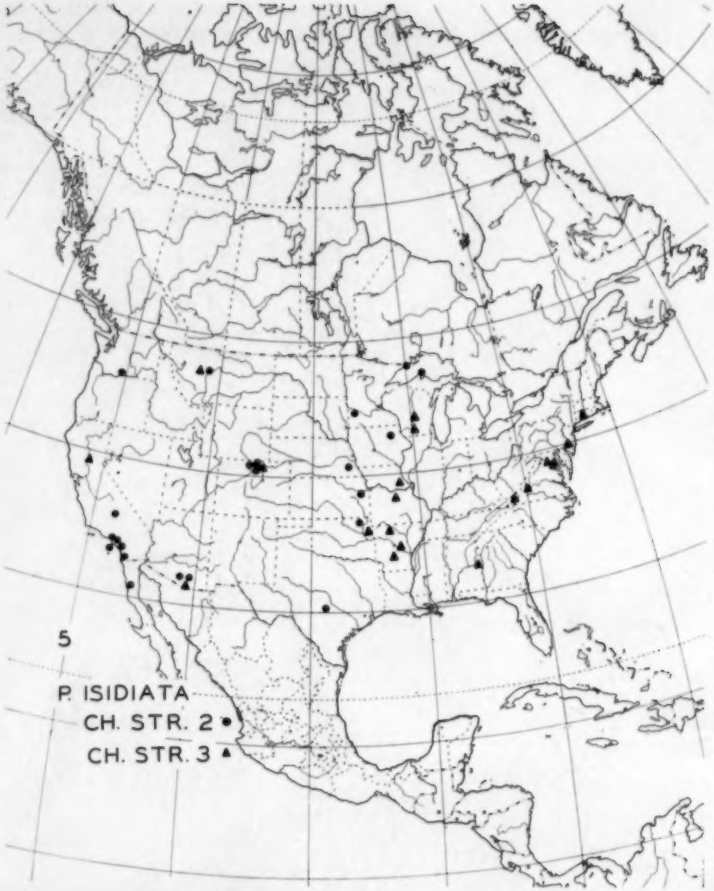


FIG. 3. *P. conspersa* Ch. str. 3. (Fumarprotocetrarie acid). FIG. 4. *P. isidiata* Ch. str. 1 (Stictic acid). The 90th meridian falls approximately along the Mississippi River.



FIGS. 5–8. Geographical distributions of members of the *P. conspersa-stenophylla* group in North America. FIG. 5. *P. isidiata* Ch. str. 2 and 3 (Salacinic and Fumarprotocetrarie). FIG. 6. *P. stenophylla* Ch. str. 1 (Salacinic acid).

FIGS. 5–8. Geographical distributions of members of the *P. conspersa-stenophylla* group in North America. FIG. 5. *P. isidiata* Ch. str. 2 and 3 (Salacinic and Fumarprotocetrarie). FIG. 6. *P. stenophylla* Ch. str. 1 (Salacinic acid).

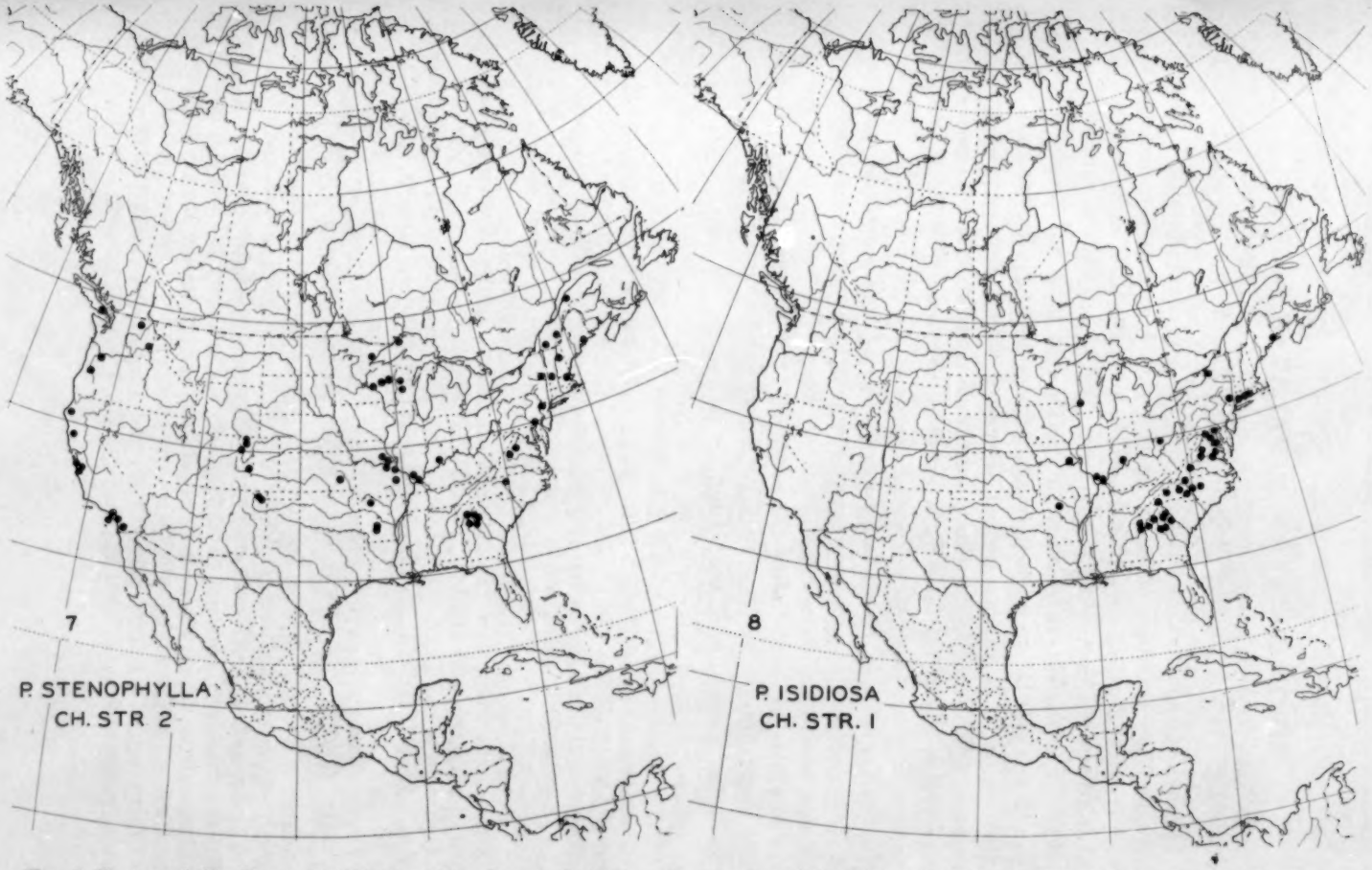


FIG. 7. *P. stenophylla* Ch. str. 2 (Stictic acid). FIG. 8. *P. isidiosa* Ch., str. 2 (Stictic acid). The 90th meridian falls approximately along the Mississippi River.

(Goode Base Map #102. Copyright by The University of Chicago. Used by permission of the University of Chicago Press.)

BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 82, NO. 1, PP. 22–29 JANUARY, 1955

NORTHWESTERN HIMALAYAN MOSSES

EDWIN B. BARTRAM

Through the courtesy of Dr. Rogers of the New York Botanical Garden I have had the privilege of studying two rather extensive collections of mosses from the northwestern Himalayas made by Dr. R. R. Stewart between 1933 and 1946. An interesting feature of these collections is the rather broad representation of eastern Himalayan species that have not been recorded by Brotherus and Dixon in their several papers dealing with the moss flora of this region. It is curious to find associated with the many well known European and North American plants such typical oriental species as *Anomobryum cymbifolium, Bryum cellulare, Philonotis Griffithiana, Trachypodopsis crispatula, Meteorium Buchanani, Floribundaria floribunda, Meteoriopsis reclinata, Haplocladium capillatum, Erythrodontium julaceum* and *Taxiphyllum taxirameum,* none of which have been recorded before from this area to my knowledge.

A complete series including the cotypes of the new species is deposited in the herbarium of the New York Botanical Garden and a representative series in the herbarium of the writer.

FISSIDENTACEAE

FISSIDENS BRYOIDES Hedw. N. W. Frontier Province: Abbottabad, 4000–5000 ft., No. 13669b.

FISSIDENS GRANDIFRONS Brid. United Provinces: Mussoorie, Landour, in water, No. 14859.

DITRICHACEAE

DITRICHUM PUSILLUM (Hedw.); E. G. Britt. United Provinces: Mussoorie, Landour, 6000–7000 ft., Nos. 14491, 14492.

DISTICHIUM CAPILLACEUM (Hedw.) Bry. Eur. Kashmir: Hai Nagkolahoi region, c. 13000 ft., No. 12497a. Mt. Aspharwat above Gulmarg, 14000 ft., No. 8859a.

DISTICHIUM INCLINATUM (Hedw.) Bry. Eur. Kashmir: above Shigar, Baltistan, 9000 ft., No. 20606. Rama above Astor, in swamp, 10000 ft., No. 22937.

DICRANACEAE

TREMATODON CAPILLIFOLIUM C. M. ? immature. United Provinces: Edgehill Villa, Landour, 6500 ft., No. 15630.

DICRANELLA VARIA (Hedw.) SCHP. Rawalpindi District: Muree, 6000 ft., Nos. 13397a 13388.

CAMPYLOPUS WALKERI MITT. ? sterile. United Provinces: Jabberkhet, Landour, Mussoorie, c. 7000 ft., No. 14967.

ONCOPHORUS VIRENS (Hedw.) BRID. Kashmir: Satpura Pass above Skardu, c. 14000 ft., No. 20251a.

SYMBLEPHARIS HELICOPHYLLA MONT. Punjab: Changla Gali, Murree Hills, 8000–9000 ft., No. 13930, 13933a. Pakistan: Changla Gali, Murree Hills, 8000–9000 ft., leg. Mohindar Nath. No. 60.

DICRANUM KASHMIRENSE BROTH. Kashmir: Gulmarg, 8000–9000 ft., Nos. 15490, 15494. Ferozepur Nulla below Gulmarg, 7000 ft., No. 14799. Pahlgam, Lidder Vy., 9000 ft., Nos. 21731, 21738, 21813. Fras Nag, Pir Panjal Range, 9000 ft., Nos. 23104b, 23230.

POTTIACEAE

WEISIA WIMMERIANA (Sendt.) Bry. Eur. Punjab: Murree, Rawalpindi District, 6000 ft., No. 13626, 13397. Kashmir: soil, leg. Mohindar Nath, No. 60.

HYMENOSTOMUM TORTILE (Schwaegr.) Bry. Eur. Kulu, Panjab, soil leg. Mohindar Nath, No. 76.

HYMENOSTYLIUM RECURVIROSTRUM (Hedw.) DIX. United Provinces: Mussoorie, Landour and vicinity, 4500–7000 ft., Nos. 14322, 14326, 14477, 15011, 14551A, 16921.

TIMMIELLA ANOMALA (Bry. Eur.) LIMP. United Provinces: Mussoorie, E. Landour Dhobi Ghat, 6000–6500 ft., Nos. 14472, 14480. Tehri Road, toward Dhanaulti, 7000 ft., No. 21272a, 21272b. Kashmir: below Bagicha, Indus Valley, c. 9000 ft., No. 20965. Below Olding Thang, Indus Valley, c. 8500 ft., No. 21027. Punjab: Murree, Rawalpindi District, 6000 ft., No. 13396, 13399; near Rawalpindi, north Punjab, No. 13627. N. W. Frontier Province: Abbottabad, 4000–4500 ft., Nos. 13669, 13675, 13718. Attock, Indus River, 1000 ft., No. 13651. Pakistan: Changla Gali, Murree Hills, 8000 ft., leg. Molindar Nath, No. 58. Pulga, Parhatti Valley, 7500 ft., leg. Mohindar Nath, No. 72. Kulu, Panjah, soil, leg. Mohindar Nath, No. 75.

HYOPHILA INVOLUTA (Hook.) JAEG. United Provinces: Mussoorie, Landour and vicinity, 4500–7000 ft., Nos. 14254a, 14360, 14500, 14550a, 14563. Punjab: Murree, Rawalpindi District, 6000–7000 ft., 13385, 13386, 13389, 13391a, 13394. N. W. Frontier Province: Abbottabad, 4000–4500 ft., No. 13722. Attock District: Jualar, 1500 ft., 16310.

DIDYMODON RECURVIROSTRIS (Hedw.) JENNINGS. Kashmir: soil, leg. Mohindar Nath, Nos. 77, 78.

BARBULA ICMADOPHILA SCHP. United Provinces: Woodstock, Landour, 6000 ft., No. 15599.

BARBULA GREGARIA (Mitt.) JAEG. Punjab: Changla Gali, Murree Hills, 8000–9000 ft., No. 13932a.

Barbula Stewartii Bartr. sp. nov. Caespitosa, caespitibus densis, viridibus; Caulis 5–6 mm. altus, erectus; folia sicca flexuosa, humida late patentia, ad 2 mm. longa, carinato-concava, e basi ovata sensim subulato-acuminata; marginibus erectis, integerrimis; costa valida, in subulam carnosam, flexuosam producta; cellulis superioribus subquadratis, diam. 6–7 μ, papillosis, basilaribus breviter rectangularibus, parietibus teneris, Folia perichaetialia intima e basi oblonga longe subulato-acuminata, tenerrime reticulata; seta 5–6 mm. longa, erecta, rubra; theca erecta, oblonga, gymnostoma; operculum conico-rostratum.

Kashmir: Brarhaj above Pahlgam, 7500 ft., by river No. 21694.

A unique species characterized by the absence of a peristome and the costa excurrent in a flexuous, fleshy, papillose subula.

DESMATODON LATIFOLIUS (Hedw.) BRID. Kashmir: Deosai Plains, 13000 ft., No. 20052.

TORTULA SUBULATA HEDW. Kashmir: soil, Mohindar Nath, No. 56.

GRIMMIACEAE

GRIMMIA LAEVIGATA BRID. Punjab: Abbottabad, N. W. Frontier Province, 4000–4500 ft., No. 13725.

FUNARIACEAE

FUNARIA PILIFERA BROTH. United Provinces: Mussoorie, east of Landour, Dhobi Ghat, 5500–6000 ft., No. 14482a. Edgehill Villa, Landour, 6500 ft., No. 15632a.

FUNARIA PHYSCOMITRIOIDES MONT. Punjab: Rawalpindi, 1700 ft., No. 14471a. Immature; determined from the description.

FUNARIA HYGROMETRICA HEDW. United Provinces: Mussoorie, Jabberkhet, 6000–7000 ft., No. 14191. Landour and vicinity, 6000–7000 ft., Nos. 14312, 14315, 14319, 14495. Rawalpindi District, 1700–7000 ft. 13392, 13395, 14601a, 13700a, 13799a. Kashmir: Verinag, Banihal Road, 5500 ft., No. 14066.

BRYACEAE

MIELICHHOFERIA BADHWARII DIX. Kashmir: Kamri Pass, 10000–11000 ft., No. 22669.

POHLIA ACUMINATA HOPPE & HORNSCH. United Provinces: Landour and vicinity, 6000–7000 ft., Nos. 14321, 14325, 14487. Dharmeala, Panjah, 4000–6000 ft., leg. Mohindar Nath, No. 74.

POHLIA NUTANS (Hedw.) LINDB. Kashmir: Apharwat above Gulmarg, 13000 ft., No. 14046a; Burji La above Skardu, 15000 ft., No. 21121; Deosai Plains, 13000 ft., No. 19939.

POHLIA GRACILIS (Schleich.) LINDB. Kashmir: above Rattu, upper Indus Valley, on Astoi Stream, 9500 ft., No. 18806.

Pohlia Stewartii Bartr. sp. nov. Dioica; flores masculi majusculi, capitulati; dense caespitosa, flavo-viridis, gracilis, fragilis; caulis ad 1.5 cm. altus, laxe foliosus; folia sicca valde contorta humida patentia, 1.5–2 mm. longa, c. 0.7 mm. lata, ovato-lanceolata, anguste acuminata; marginibus planis, integris; costa breviter excurrente; cellulae hexagonae, laxae, d 35 μ longae, versus margines in seriebus 1–2 lineares, limbum vix distinctum formantes. Seta gracilis, purpureus, ad 3 cm. altus; theca pendula, e collo brevi turgide elliptica; peristomium pallidum, dentes ad 0.32 mm. longi, minutissime papillosi, endostomium hyalinum, processus rimosi, cilia bina nodosa; operculum conicum, obtusum.

Kashmir: Deosai Plains, c. 13000 ft., No. 20006a, 20025, 20026a type, 20049a.

Possibly near P. rigidifolia (Dix. & Badhw.) but apparently quite distinct in the shorter stems, sharply acuminate leaves, excurrent costa and especially the leaves strongly contorted when dry.

MNIOBRYUM ALBICANS (Wahlenb.) LIMP. Kashmir: Uri-Poonch Road, c. 7000 ft. No. 13979; Maspid Gshi Gangobal Lakes, alpine, No. 18385a. Punjab: Changla Gali, Murree Hills, c. 8000 ft., No. 13929.

ANOMOBRYUM FILIFORME (Dicks) HUSN. United Provinces: Mussoorie, Landour and vicinity, 6000 ft., No. 14476, 15633, 15633a.

ANOMOBRYUM CYMBIFOLIUM (Lindb.) BROTH. ? sterile. United Provinces: near Half Way House, 4500 ft., No. 14563a.

ANOMOBRYUM PELLUCIDUM DIX. & BADHW. Kashmir: Burji La above Skardu, 15000 ft., No. 20121a.

LEPTOBRYUM PYRIFORME (Hedw.) SCHIMP. Kashmir: Verinag, Banihal Road, 5500 ft., No. 14066a.

BRYUM PENDULUM (Hornsch) SCHIMP. Kashmir: Skardu, Baltistan, 8000 ft., No. 20374.

BRYUM CELLULARE Hook. Punjab: Rawalpindi or vicinity, No. 14600a,

BRYUM PALLESCENS SCHLEICH. Kashmir: Deesai Plains, 13000 ft., No. 20088; Satpura Pass above Skardu, 14000 ft., No. 20251, 21202, 21205; Baltal Sind Vy., 9500 ft., No. 21279; Fras Nag, Pir Panjal Range, 9000 ft., No. 23197; Burzil Pass, 12000 ft., 22085; on soil, leg. Mohindar Nath, No. 67. Punjab: Abbottabad, N. W. Frontier Prov., 4000–4500 ft., No. 13713. Rotang Pass, Kulu to Lahul, 13000 ft., leg. Mohindar Nath, No. 73. Dharmsala near Dal Lake, 5000 ft., leg Mohindar Nath, No. 71.

BRYUM CORONATUM SCHWAEGR. United Provinces: Mussoorie, Dehra Dun, 2200 ft., No. 14678.

BRYUM ARGENTEUM HEDW. var LANATUM Bry. Eur. United Provinces: Mussoorie, Edgehill Villa, Landour, 6500 ft., Nos. 15627, 15628.

BRYUM TURBINATUM (Hedw.) SCHWAEGR. Kashmir: Panchtaim Road to Amarmath, through Trahad Walla, 12000 ft., No. 19282a; Burzil Chowki, Gilgit Rd., 11000 ft., No. 19750; Thalls La, Baltistan, 10000 ft., No. 20671.

BRYUM CIRRATUM HOPPE & HORNSCH. Kashmir: above Dangarpur, near Gulmarg, 9000 ft., No. 14834.

BRYUM CAPILLARE HEDW. United Provinces: Landour and vicinity, 4000–7000 ft., Nos. 14319a, 14549, 14563a, 14564a, Punjab: Murree, Rawalpindi Dist., 6000–7000 ft., No. 13387; Abbottabad, N. W. Frontier Prov., 4000–4500 ft., No. 13720. Kashmir: Satpura Pass, north slope, 14000 ft., No. 20304.

BRYUM GAMBLEI BROTH. ex desc. Kashmir: Sonamarg, Sind Vy., 9000–10000 ft., No. 22404.

BRYUM ULIGINOSUM (Brid.) Bry. Eur. Kashmir: Kamri Pass, 10000–11000 ft., No. 22708.

BRYUM WEIGELII SPRENG. ex desc. Kashmir: Deosai Pass, 13500 ft., No. 22154a; Deosai Pass, upper Kishinganga Valley above Miniriang, No. 22152a.

BRYUM PSEUDOTRIQUETRUM (Hedw.) SCHWAEGR. Kashmir: Deosai Plains, in swamps, 13000 ft., No. 22205; Rama above Astor, in swamp, 10000 ft., No. 22927, 22932, 22936.

RHODOBRYUM ROSEUM (Bry. Eur.) LIMP. Kashmir: below Aliabad, Poonch side, c. 7000 ft., No. 12013. Punjab: Murree, Rawalpindi Dist., 6000–8000 ft., Nos. 13398, 23414; Abbottabad, N. W. Frontier Prov., 4000–4500 ft., No. 13712.

MNIACEAE

MNIUM LONGIROSTRUM BRID. United Provinces: north slope of Landour, 6000–7000 ft., No. 13502b.

MNIUM LYCOPODIOIDES (Hook.) SCHWAEGR. Kashmir: Brarhaj above Pahlgam, 7500 ft., No. 21693.

AULACOMNIACEAE

AULACOMNIUM PALUSTRE (W. & M.) SCHWAEGR. Kashmir: Burzil Showki, Gilgit Rd., 11000 ft., No. 19769.

MEESEACEAE

AMBLYODON DEALBATUS P. BEAUV. Kashmir: Rama above Astor, 11000 ft., No. 22938.

Not previously recorded from the Himalayan region.

BARTRAMIACEAE

PLAGIOPUS OEDERI (Gunn) LIMP. Kashmir: Mt. opposite Pahlgam, 8000–9000 ft., No. 21733.

BARTRAMIA ITHYPHYLLA BRID. United Provinces: Mussoorie, Landour and vicinity, 6000–7000 ft., Nos. 13502a, 14502, 14672a, 16973.

PHILONOTIS GRIFFITHIANA (Wils) MITT. United Provinces: Mussoorie, Edgehill Villa, Landour, 6500 ft., No. 15632.

PHILONOTIS FALCATA (Hook). MITT. ? sterile. United Provinces: Jabberkhet, near Landour, 7000 ft., No. 14976a.

PHILONOTIS FONTANA (Hedw.) BRID. Kashmir: Burzil Chowki, Gilgit Rd., 1000 ft., Nos. 19750a, 19768; Rama above Astor, in swamp, 10000 ft., No. 22933. Khund, Parbatti Valley, between Bhun Bhuni and Khir gango, 10000 ft., leg. Mohindar Nath, No. 63.

PHILONOTIS CALCAREA (Bry. Eur.) SCHP. Kashmir: Tulion above Pahlgam, in swamp, 10000–11000 ft., No. 21867a.

LEUCODONTACEAE

LEUCODON SCIUROIDES (Hedw.) SCHWAEGR. United Provinces: Mussoorie, Landour and vicinity, 6000–7000 ft., Nos. 14316, 21055a.

TRACHYPODACEAE

TRACHYPODOPSIS CRISPATULA (Hook.) FLEISCH. United Provinces: Mussoorie, Landour and vicinity, 6000–7000 ft., Nos. 14354, 14474, 16683c.

METEORIACEAE

METEORIUM BUCHANANI (Brid.) BROTH. United Provinces: Landour and vicinity, 6000–7000 ft., Nos. 13503a, 14496, 15578.

FLORIBUNDARIA FLORIBUNDA (Doz. & Molk.) FLEISCH. United Provinces: Mussoorie, Landour and vicinity, Midlands Valley, 6000 ft., No. 16949.

METEORIOPSIS RECLINATA (C. M.) FLEISCH. United Provinces: Mussoorie, north slope, Landour, 6000–7000 ft., Nos. 14501, 16101a.

NECKERACEAE

CRYPTOLEPTODON FLEXUOSUS (Harv.) REN. & CARD. United Provinces: Mussoorie, Landour, 6000–7000 ft., Nos. 14154, 21219.

NECKERA PENNATA HEDW. Kashmir: Pahlgam, 7000–8000 ft., No. 21541.

LESKEACEAE

PSEUDOLESKEA ATROVIRENS (Dicks.) Bry. Eur. Kashmir: Gulmarg, 9000 ft., No. 15531 in part.

THUIDIACEAE

ANOMODON VITICULOSUS (Hedw.) H. & T. Punjab: Murree, 6000–7000 ft., No. 23391.

CLAOPODIUM NERVOSUM (Harv.) FLEISCH. United Provinces: Dhobi Ghat, E. Landour, 6000–6500 ft., No. 14479 in part.

CLAOPODIUM LONGIPILUM DIX. Punjab: Abbottabad, N. W. Frontier Prov., 4000–4500 ft., No. 13717.

HAPLOCLADIUM CAPILLATUM (Mitt.) BROTH. Kashmir: Changlo Goli, Murree Hills, 8000 ft., No. 13924a.

Haplocladium himalayanum Bartr. sp. nov. Autoicum: gracile, caespitosum, caespitibus depressis, viridibus, intus fuscescentibus; caulis prostratus, irregulariter pinnatum ramosus, paraphyllis filiformibus sparse vestitus, ramis subpinnatum ramulosis; folia caulina erecto-patentia, late ovata, raptim subulato-lanceolata, ad 1.4 mm. longa. 0.7 mm. lata basi biplicata; margines inferne recurvi, subintegri; costa valida, in subulam desinente; cellulae irregulariter oblongo-hexagonae, laeves. Folia ramea minora, sicca contorta, incurva, brevius acuminata; cellulae minute papillosae. Seta rubra, tenuis, c. 1.5 cm. longa; theca horizontalis, oblongo-cylindrica, sicca arcuata, sub ore valde contracta.

United Provinces: Jabberkhet, 6000–7000 ft., No. 14192.

According to Thériot's revision of the asiatic species[1] this plant might be included in the Section Evanidinervium near H. Laraminati (Broth. & Par.) Broth. To judge from the description of the latter species the Himalayan plants are coarser with the stem and branch leaves almost twice as large. H. capillatum (Mitt.) Broth. differs widely in the stem leaves with the costa long excurrent.

THUIDIUM SPARSIFOLIUM (Mitt.) JAEG. Kashmir: Landour, 6000–7000 ft., No. 14672b.

THUIDIUM ASSIMILE (Mitt.) BROTH. Kashmir: Pahlgam, 7200 ft., on great rock, No. 21774.

THUIDIUM CYMBIFOLIUM (Doz. & Molk.) Bry. Jav. United Provinces: Landour and vicinity, 6000–6500 ft., Nos. 14314, 14487a, 14501a.

AMBLYSTEGIACEAE

CRATONEURON FALCATUM (Brid.) ROTH Kashmir: Mengandob-Gadsar, near Gangabal Lakes, 11000-12000 ft., No. 18293; above Chorwan, Kishenganga Vy., 9000 ft., No. 19727.

AMBLYSTEGIUM SERPENS (Hedw.) Bry. Eur. Kashmir: above Shigar, Baltistan, 9000 ft., No. 20606a.

CAMPYLIUM HISPIDULUM (Brid.) MITT. Kashmir: Snow Nullah, Pahlgam, 8000 ft., No. 21880.

[1] Le genre Haplocladium en Asie et en Afrique.—Ann. d. Crypt. Exot. 3: 57–100. 1930.

HYGROHYPNUM PALUSTRE (Hedw.) LOESKE Kashmir: Fras Nag, Pir Panjal Range, 9000 ft., Nos. 23190A, 23211A: Brarhaj above Pahlgam, 7500 ft., Nos. 21692, 21693.

DREPANOCLADUS UNCINATUS (Hedw.) WARNST. Punjab: Fras Nag, Pir Panjal Range, 9000 ft., 23212A.

BRACHYTHECIACEAE

BRACHYTHECIUM SALEBROSUM (Hoffm.) Bry. Eur. Punjab: Murree, Rawalpindi Dist., 6000–7000 ft., Nos. 13393, 13400; Changla Gali, Murree Hills, 8000–9000 ft., No. 13931a.

BRACHYTHECIUM PROCUMBENS (Mitt.) JAEG. Pakistan: Changla Gali, Murree Hills, 8000 ft., leg. Mohindar Nath, Nos. 59, 61.

BRACHYTHECIUM PLUMOSUM (Hedw.) Bry. Eur. Punjab: Murree, Rawalpindi Dist., 6000–7000 ft., No. 13391.

RHYNCHOSTEGIUM HERBACEUM (Mitt.) JAEG. Punjab: Murree, Rawalpindi Dist., 6000–7000 ft., No. 13390.

RHYNCHOSTEGIUM PLANIUSCULUM (Mitt.) JAEG. United Provinces: Mussoorie, Landour, rocks, 6500 ft., No. 14313.

ENTODONTACEAE

ERYTHRODONTIUM JULACEUM (Hook.) PAR. United Provinces: Mussoorie, Landour, on soil, 6000–7000 ft., No. 14677.

ENTODON MYURUS (Hook.) JAEG. United Provinces: Mussoorie, Landour and vicinity, 4500–7000 ft., Nos. 14304, 14475, 14478, 14478a, 14552a, 15602, 15617B, 17039A, 21323. Punjab: Abbottabad, ground, 4000–5000 ft., No. 13719. Dharmsala, Panjale, leg. Mohindar Nath, No. 64.

LEVIERELLA FABRONIACEA C. M. United Provinces: Landour, to Half Way House 4500–6500 ft., No. 14554A.

HOLMGRENIA INTRICATA (Hartm.) LINDB. Kashmir: Fras Nag, Pir Panjal Range, 9000 ft., on rocks, No. 23236A.

PLAGIOTHECIACEAE

STEREOPHYLLUM WIGHTII (Mitt.) JAEG. United Provinces: Midland Valley, Landour, 6000 ft., No. 14334.

HYPNACEAE

PLATYGYRIUM REPENS (Brid.) Bry. Eur. United Provinces: Jabberkhet, beyond Landour, 7000 ft., No. 14356.

PYLAISIA AUREA (Hook.) BROTH. Dharmsala, Panjab, leg. Mohindar Nath, No. 65.

HOMOMALLIUM SIMLAENSE (Mitt.) BROTH. Kashmir: Aliabad, Uri-Poonch Rd., 7000 ft., No. 13994A. Punjab: Murree, Rawalpindi Dist., 6000–8000 ft., No. 13389A; Changla Gali, Murree Hills, 8000–9000 ft., Nos. 13927, 13931, 23415; leg. Mohindar Nath, Nos. 54, 55. Markanda beyond Simla, 9000 ft., leg. Mohindar Nath, No. 69. McLeod Ganj, Dharmsala, 4500–5500 ft., leg. Mohindar Nath, No. 70.

HYPNUM REPTILE MX. Kashmir: Baisarran, above Pahlgam, 8000 ft., No. 21876.

ISOPTERYGIUM PULCHELLUM (Hedw.) JAEG. var. NITIDULUM (Wahl) BROTH. Punjab: N. W. Frontier Prov., 4000–4500 ft., Nos. 13669a, 13664, 13668, 13715, 13721.

TAXIPHYLLUM TAXIRAMEUN (Mitt.) FLEISCH. United Provinces: E. of Landour, Dhobi Ghat, 5500–6500 ft., No. 14482. Punjab: Abbottabad, N. W. Frontier Prov., 4000–4500 ft., No. 13714.

HYLOCOMIACEAE

MACROTHAMNIUM SUBMACROCARPUM (Hampe) FLEISCH. United Provinces: Landour, east of Dhobi Ghat, 6000–6500 ft., No. 14473.

POLYTRICHACEAE

POGONATUM PERICHAETIALE (Mont.) JAEG. United Provinces: Mussoorie, Jabberkhet, 7000 ft., No. 15579.

POLYTRICHUM JUNIPERINUM HEDW. Kashmir: Khillanmarg above Gulmarg, 10000 ft., No. 14045A; Rama above Astor, 10000 ft., No. 22935A, 22898A: Sanamarg 10000 ft., No. 22406B. Narkanda beyond Simla, 9000 ft., leg. Molindar Nath, No. 68.

ATRICHUM OBTUSULUM (C. M.) JAEG. Kashmir: Pahlgam, 9000 ft., No. 21812; on soil, leg. Molindar Nath, No. 57.

POGONATUM ALPINUM (Hedw.) ROEHL. Khund, Parbatti Valley, between Bhun Bhuni and Khir ganga, leg. Molindar Nath, No. 62.

BUSHKILL, PIKE COUNTY
PENNSYLVANIA

BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 82, No. 1, pp. 30–38 JANUARY, 1955

CYTOLOGY OF THE TRADESCANTIEAE

ROBERT P. CELARIER

The value of cytology to the systematist in phylogenetic studies has been pointed out by many workers (Stebbins 1950) and the specific aid that the Commelinaceae might derive from such a study was suggested by Anderson and Sax (1936) in their cytological monograph of the family. Studies in the cytology and the taxonomy of the family have not been abundant in the past fifteen years but some have been made. The most recent taxonomic treatment was that of Woodson (1942) in which some generic changes were made and the tribe Tradescantieae was delimited as it is used in this study. The tropical members of this tribe are poorly understood, both cytologically and taxonomically, and monographs in both phases are badly needed. It is hoped that this study may be of some value toward that end and will bring the cytological literature up to date.

Cytological studies were made using the smear technique and the chromosomes were stained in aceto-carmine or orcein. Herbarium specimens with photomicrographs have been made for most of the species studied and these are deposited in the Missouri Botanic Garden Herbarium.

Acknowledgment is due R. E. Woodson, U. T. Waterfall, and H. J. Kidd for assistance in identifying these materials.

Tripogandra. A large number of genera have been proposed in the past to exclude different elements from *Tradescantia* because of the dissimilarity of the stamens or the absence of foliaceous bracts. Woodson (1942) places them all in this genus.

Two basic chromosome numbers, 6 and 8, are known. Eight appears to be widespread but at present only two cases of six are known.

Among those with a basic number of eight, two have been previously recorded, *T. disgrega* by Darlington (1937), and *T. grandiflora* by Wu (1941). *T. disgrega* is a diploid with chromosomes of medium size, of which one is sub-median and seven are sub-terminal in their primary constrictions. *T. grandiflora* is a tetraploid also with medium sized chromosomes of which 14 have terminal or sub-terminal constrictions and two are median. *T. elongata* has been reported as 2n = ca. 50 (Simmonds 1954) and in all probability has eight as a basic number.

In this study *T. pflanzii*[1] and *T. amplexicaulis* are found to be diploids

[1] The identity of this species and its inclusion in this genus is questionable. The material was received as *Descantaria pflanzii* but it has not been checked against the original description. It has many characteristics of *Tripogandra cumanensis* and also some of *T. elongata* but is certainly not typical of either. To my knowledge the species has not been previously treated as Tripogandra, nevertheless it has been included here in this study because of its cytological and morphological similarities.

and *T. cumanensis* is a hexaploid with 24 bivalents (this might also be considered as an octoploid in the six series).

T. pflanzii is a native of South America and our material was furnished from the Buenos Aires area by A. Castellanos. The chromosomes of this species are essentially similar in size and morphology to *T. disgrega* (fig. 9).

TABLE 1. *Karyology of Tradescantieae*

Genus and Species	Haploid Number	Constriction				Authority
		Size	Med.	Term.	Fig.	
Tripogandra disgrega Wood.	8	Med.	1	7		Darlington (1937)
T. grandiflora Wood.	16	Med.	2	14		Wu (1941)
T. pflanzii	8	Med.	1	7	9	C.
T. amplexicaulis Wood.	8	Med.	6	2	7	C.
T. cumanensis Wood.	24	Med.	—	—		C.
T. rosea Wood.	6	Large	2	4	2	A & S (1936) Giles, C. (1942)
T. graminea	6	Large	2	4		Giles (1942)
T. graminea	12	Large	4	8		Giles (1942)
T. graminea	18	Large	6	12		Giles (1942)
Tradescantia "virginiana" species	6	Large	6	0	1	A & S (1936) C.
Tradescantia "virginiana" species	12	Large	12	0		A & S (1936)
T. iridescens Booth ex Lindl.	6	Large	3	3		A, M & W (1949)
T. commelinoides R & S	7	Large	7	0	6	C.
T. micrantha Torr.	13	Med.	0	13	3	A & S (1936) C.
T. fluminensis Vell.	30	Small	0	30		Darlington (1929)
Callisia repens L.	6	Med.	2	4		A & S (1936)
C. fragrans Wood.	6	Med.	2	4		A & S (1936)
C. sp.	6	Med.	1	5	5	C.
Campelia zanonia H.B.K.	8	Large	6	2		A & S (1936) C.
C. zanonia H.B.K.	8	Large	2	6		Darlington (1937) Simmonds (1954)
Rhoeo discolor Hanse	6	Med.	4	2		Darlington (1929) A & S (1936) C.
Setcreasea breviflora Rose	6	Med.	6	0		Richardson (1935) C.
S. breviflora	12	Med.	12	0		Darlington (1929) Richardson (1935) C.
S. breviflora	11–12	Med.	11–12	0		C.
S. breviflora	18	Med.	18	0		A & S (1936)
S. pallida Rose	6	Med.	6	0	4	C.
S. pallida Rose	18	Med.	18	0	8	C.
S. tumida Rose	12	Med.	12	0		C.
Zebrina pendula Schnitzel	12	Med.	2	10	10	Darlington (1929) C.
Weldenia candida Schult.	12	Large	App. 6	App. 6		A, M & W (1949)

The meiotic divisions show either 8 bivalents or 6 bivalents and a tetravalent. There are occasionally found lagging chromosomes at anaphase and telaphase and micro-nuclei at the dyad spore stage.

T. amplexicaulis Woodson was also collected in the Buenos Aires area and supplied for this study by A. Castellanos. This species has eight chromosomes of medium size, however it is different morphologically from *T. pflanzii*

having 6 chromosomes with median or sub-median and 2 with terminal constrictions (fig. 7). The meiotic configuration at MI consists of univalents, bivalents, trivalents, and tetravalents. Frequencies of these are given in Table 2. The most frequent condition consisted of 6 bivalents with the other four chromosomes associated either as a tetravalent (fig. 17) or a univalent + a trivalent (fig. 18).

TABLE 2. *Metaphase I in Tradescantieae*

Genus and Species	Av. per Cell								Authority
	2n	I	II	III	IV	V	VI	Fig.	
T. disgrega	16	—	Mostly 8.00	—	—	—	—		Darlington (1937)
T. pflanzii	16	0.08	7.36	0.00	0.30	0.00	0.00		C.
T. amplexicaulis	16	0.40	6.00	0.13	0.67	0.00	0.00	17, 18	C.
T. cumanensis	48	—	Mostly 24.00	—	—	—	—	16	C.
T. elongata	c.50		Extremely irregular						Simmonds (1954)
T. rosea	12	0.00	6.00	0.00	0.00	0.00	0.00		C.
T. graminea	12	.00	6.00	.00	.00	.00	.00		Giles (1942)
Callasia fragrans	12	0.00	6.00	0.00	0.00	0.00	0.00		Wu (1941)
C. sp.	12	0.00	6.00	0.00	0.00	0.00	0.00		C.
Campelia zanonia	16	0.00	4.00	0.00	2.00	0.00	0.00		A & S (1936) Darlington (1937)
C. zanonia	16	0.00	8.00	0.00	0.00	0.00	0.00		Simmonds (1954)
Tradescantia "virginiana"	12	0.00	6.00	0.00	0.00	0.00	0.00		A & S (1936) C.
T. "virginiana"	24	.23–.42	4.95	.23–.42	2.68–2.87	—	—		Brown et. al. (1951)
T. "virginiana"	24	0.00	4.65	0.00	3.60	0.00	0.00		A & S (1936)
T. commelinoides	14	0.00	6.60	0.00	0.10	0.00	0.00	14	C.
T. micrantha	26	0.00	12.50	0.00	0.20	0.00	0.00	15	C.
Setcreasea breviflora	12	0.00	6.00	0.00	0.00	0.00	0.00		Richardson (1935)
S. breviflora	24	1.79	5.93	0.40	2.26	0.00	0.04		Richardson (1935)
S. breviflora	23	1.16	8.79	0.53	0.89	0.00	0.00		C.
S. breviflora	36	—	—	—	—	—c.	3.00		A & S (1936)
S. pallida	12	0.00	6.00	0.00	0.00	0.00	0.00		C.
S. pallida	36	0.57	12.36	0.31	0.92	0.23	0.69	19, 20	C.
Zebrina pendula	24	—	Mostly 12.00	—	Occasional	—	—		Darlington (1929)
Z. pendula	24	0.00	12.00	0.00	0.00	0.00	0.00		Simmonds (1954)

T. cumanensis Woodson was furnished for this study by J. Leon from a seed collection made in Costa Rica. The one plant that was available for study died before studies of chromosome morphology were made. Studies of the meiotic division were made and at diakinesis and MI 24 bivalents were observed (fig. 16).

Two groups (*Cuthbertia* and *Leptorhoeo*) differ from the others in having stamens that are essentially similar. *Cuthbertia* also differs in chromosome size, number and morphology (fig. 2). Unfortunately no studies of *Leptorhoeo* have yet been made.

It seems possible that the genus *Tripogandra,* as used here, might be separated into two groups on both morphological and cytological grounds but additional genera and species must be studied cytologically before a definite decision can be made.

Callisia. The morphological and cytological similarity of *Callisia repens* and *Spironema fragrans* were pointed out by Anderson and Sax (1936) and Woodson (1942) transferred the latter to *Callisia.* These two species have six pairs of medium sized chromosomes of which two have sub-median and four terminal or sub-terminal constrictions.

Callisia sp. is believed to be from Mexico and was furnished for this study by the Floriculture department of the A. & M. College of Texas. Since the identity of this entry is not known a brief description is given.

It is a small creeping plant, rooting freely at the nodes, the leaves are ovate, 1–2 cm. long, fleshy and succulent, densely covered on both surfaces with extremely short eglandular hairs so that it is velvety, the under side is reddish-purple, upper green with white stripes, internodes 0.5–5 mm. in vegetative condition, 5 mm.–1 cm. on flowering branches. Inflorescence in paired cymes that are sessile and flowers are much congested. Pedicels triangular with long cobwebby hairs on margins; sepals deeply keeled, hyaline on margins, light green elsewhere with purple spotting at the tip; stamens 6; filaments glabrous; anthers with broad connective; petals 3, white, obovate, reflexed; ovary covered with short glandular hairs.

This entry was found to have six pairs of medium sized chromosomes but had only one with a median constriction (fig. 5) rather than two as in the previously reported species. The meiotic division was found to be regular throughout.

Tradescantia. The U. S. species of this genus, with the exception of *T. micrantha,* are morphologically and cytologically similar and they have been studied in some detail (Anderson and Sax 1936, Anderson and Woodson 1935, Darlington 1929, 1937; Brown, Ponewczynski and Scarborough 1951). Cytologically they were all reported by Anderson and Sax (1936) except *T. wrightii, T. pinatorum, T. Reverochoni* and *T. occidentalis* var. *scopulorum.* Both diploids (n = 6) and tetraploids (n = 12) were found and many species were shown to have both diploid and tetraploid races. Morphologically the chromosomes were found to be large, all similar in size, and with either median or sub-median primary constrictions. Brown, Ponewczynski and Scarborough (1951) found *T. Reverochoni* to be a tetraploid and this study shows *T. occidentalis* var. *scopulorum* to be a diploid (figs. 1 and 11).

Woodson (1942) points out that there are three other morphological groups that may, with further study, be found to be distinct.

One of these includes the south Texas and Mexican species, *T. micrantha* Torr. The chromosome number and morphology were reported by Anderson and Sax (1936) but no meiotic studies were reported.

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The chromosomes of this species are very different from the "virginiana" complex in number, size, and position of constrictions (fig. 3). It has a haploid number of 13, all of which are terminal or sub-terminal in primary constriction, three of the chromosomes are large and the others are either medium or small. The meiotic division is essentially normal with 13 bivalents commonly found (fig. 15) at diakinesis and MI, but with one tetravalent frequent (Table 2). This species is the only member of the genus in which the author has consistently found the meiotic prophase to spread nicely and stain very readily and sharply.

The second type of questionable taxonomic position included *T. commelinoides* R. & S. and relatives. The entry of this species reported here was collected from the valley of Mexico by E. Matuda. One plant was received and it was potted in the greenhouse. It flowered soon afterward, produced no seed and died. It is probable that, as are most members of the genus, it was self-sterile and it may also be an annual. Cytologically it was different from any previously reported species. The chromosomes were very large and had a haploid number of seven (figs. 6 and 13). They were all median in primary constrictions, even more so than the "virginiana" complex. The meiotic behavior was regular with a predominance of seven bivalents, usually two chiasmata per bivalent and these are terminalized at diakinesis and metaphase I (fig. 14). However, in about 10% of the cells 5 bivalents + 1 quadrivalent were observed (Table 2).

The third group mentioned by Woodson is the *T. fluminensis* Vell. complex. This species was reported by Darlington (1929) as having 30 pairs of chromosomes, 3 small and 27 very small, and with the primary constrictions all terminal.

To these four cytological types may be added what appears to be another. Atchinson, Moore and Wood (1949) reported that *T. irridescens* from Mexico has six pairs of chromosomes. From their drawing the chromosomes ap-

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FIGS. 1–20. Chromosomes in the Tradescantieae. Magnification × 1350. FIGS. 1–10. Karyotypes. FIG. 1. *Tradescantia occidentalis* var. *scopulorum*. FIG. 2. *Tripogandra graminea*. FIG. 3. *Tradescantia micrantha*. FIG. 4. *Setcreasea pallida*. FIG. 5. *Callisia* sp. FIG. 6. *Tradescantia commelinoides*. FIG. 7. *Tripogandra amplexicaulis*. FIG. 8. *Setcreasea pallida*. FIG. 9. *Tripogandra pflanzii*. FIG. 10. *Zebrina pendula*. FIGS. 11–13. First somatic division of the gametophyte, showing haploid number and morphology. FIG. 11. *Tradescantia occidentalis* var. *scopulorum*. FIG. 12. *Setcreasea pallida*. FIG. 13. *Tradescantia commelinoides*. FIGS. 14–20. Meiotic configurations at late diakineses and metaphase I. FIG. 14. *Tradescantia commelinoides* with 7 bivalents. FIG. 15. *T. micrantha* with 13 bivalents, 3 very large and 2 very small. FIG. 16. *Tripogandra cumanensis* with 24 bivalents, 2 overlapping. FIG. 17. *T. amplexicaulis* with 4 bivalents + 2 quadrivalents (one a ring and the other a chain). FIG. 18. *T. amplexicaulis* with 1 univalent + 6 bivalent + 1 trivalent. FIG. 19. *Setcreasea pallida*, hexaploid with 16 bivalent + 1 quadrivalent. FIG. 20. *Setcreasea pallida* showing a univalent and a hexavalent (only a part of the cell is included).

pear to be large, two with median, three sub-median and one with a terminal constriction.

From a cytological standpoint *Tradescantia* is still extremely large and complex with at least four basic numbers and five karyotypes. It seems probable, considering both morphology and cytology, that the genus could be divided into at least four groups.

Setcreasea. Although there are only a few species of this genus generally recognized, it is extremely variable both morphologically and cytologically. It is apparently in an active state of evolution in which euploidy, aneuploidy, structural hybridity, and hybridization appear to be playing a part.

S. brevifolia Rose is extremely variable and diploid, tetraploid and hexaploid forms have been studied.

The diploid has six pairs of chromosomes with a completely regular meiotic division (Richardson 1935). The chromosomes are medium-large in size, three with median constrictions and three sub-median.

The chromosome size and morphology of the tetraploid is similar. The meiotic division has been studied in detail by Richardson (1935) and these data are used in Table 2. An entry from West Texas furnished by G. Webster appears to be similar.

One entry, believed to be from Mexico, was supplied by W. V. Brown. It was found to be $4n-1$ with chromosome morphology similar to the diploid. The meiotic behavior is given in Table 2. Anaphase I and TI was found to have a high proportion (10%) of cells with a bridge + fragment, but otherwise the behavior was normal. The distribution of chromosomes to the daughter cells at TI was 12:11 in 86% of the cells, 10:13 in 6% and less than 23 chromosomes countable in the remaining 8%.

The hexaploid was reported on by Anderson and Sax (1936) and they state that about 50% of the chromosomes were associated as hexavalents.

Since the identification of the following is not certain a brief morphological description is given with each.

S. pallida Rose. Stems fleshy, decumbent, up to 40–45 cm. long, short internodes, leaves oblong, glabrous except for scattered eglandular hairs along the margins, 8–13 cm. long, 3–4 cm. broad, green with a tinge of purple, petals light pink.

One entry was found in Baton Rouge, Louisiana where it had escaped from cultivation. It was found to be a diploid and the meiotic division was completely regular (Table 2) with six bivalents at metaphase I. The chromosomes are medium in size and all six have either median or sub-median constrictions (figs. 4 and 12).

Another entry was studied and found to be a hexaploid. This was supplied by the Floriculture Dept. of the A. & M. College of Texas. It is seen from Table 2 that the irregularities in this entry are less than those reported

for *S. brevifolia.* Although hexavalents are frequently encountered (fig. 20) only one cell was found with as many as three hexavalent. Also a rather high per cent of the cells had either 18 bivalent or 16 bivalent + 1 quadrivalent (fig. 19). Although chromosome distribution to the daughter cells was observed in only a few cells (seven) at AI, it is remarkable that 18 : 18 is the only number encountered. In all of these studies the cells analyzed were restricted to those in which all of the chromosomes could be accurately determined. It is quite possible that this may have produced a bias favoring normality and this could be rather great at metaphase I where such a large number of cells was not analyzable.

The first mitotic division following meiosis is of some interest in this entry. Slides were prepared at four times in two years (two each year). Unfortunately no data were taken concerning any of the conditions, environmental or otherwise, at the time the material was taken.

Two of these slides had a high proportion of cells at metaphase and in every cell studied there were found 18 chromosomes, and few abortive cells were seen.

The other two, made the previous year, had only 66% of the cells with 18 chromosomes, 5% had 19, 6% had 20, and the remainder had either 18 + a fragment or 18 + ½ a chromosome. There was found a high percentage (approximately 75%) of abortive cells, and cells with an excessive number of chromosomes (35–60) were not uncommon.

It is suggestive that the environmental conditions may be very important in chromosome pairing in this entry.

The size and morphology of the chromosomes in this entry are very similar to the diploid (fig. 8).

S. tumida Rose. Roots tuberoid, stems decumbent and succulent, leaves lanceolate, long cobwebby hairs covering both surfaces and the margins, 8–5 cm. long, greenish purple in color, petals rose.

Material was furnished by the New York Botanical Garden as *Setcreasea* sp. Cytologically it is a tetraploid (n = 12) and the chromosomes are of medium size and with median or sub-median constrictions.

Conclusions. The other genera are but little known cytologically and what data are available are summarized in Tables 1 and 2.

Although there has been considerable cytological work in this tribe, still the majority of the species are not yet known. Nevertheless at least four basic numbers are already known of which three are definitely in an aneuploid series. Within each basic number there are probably many karyotypes from the standpoint of primary constrictions and chromosome size. No obvious karyological relationship is seen in the species which were studied but there is every reason to believe that a thorough phylogenetic study of the

tribe, including morphology, cytology, and geographical distribution, will prove most fruitful.

SUMMARY

1. The cytology of the tribe Tradescantieae, including chromosome number, morphology, and meiotic behavior, is reviewed.

2. Karyotypes not previously known for the tribe are reported for *Tripogandra amplexicaulis, Callisia* sp., and *Tradescantia commelinoides,* the latter has a new basic number (x = 7).

3. Chromosome number and morphology are also reported for *Tripogandra pflanzii, Tradescantia occidentalis* var. *scopulorum, Stecreasea brevifolia, S. pallida,* and *S. tumida.*

4. Meiotic behavior is reported for *Tripogandra pflanzii, T. amplexicaulis, T. cumanensis, Callisia* sp., *Tradescantia micrantha, T. commelinoides, Setcreasea brevifolia* and *S. pallida.*

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BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 82, NO. 1, PP. 39–49 JANUARY, 1955

NUCELLUS AND ENDOSPERM IN THE SEED OF LIMA BEAN (PHASEOLUS LUNATUS L.)

CLARENCE STERLING

In a previous paper (Sterling 1954), the writer considered the ontogeny of the seed coat of the lima bean. The present study concerns aspects of the development of the nucellus and the endosperm from flowering to organoleptic maturity of the lima bean seed, as it is commonly used for freezing. As in the earlier investigation, these data may serve the dual purpose of suggesting possible maturity indices and of advancing information of more exclusively botanical interest.

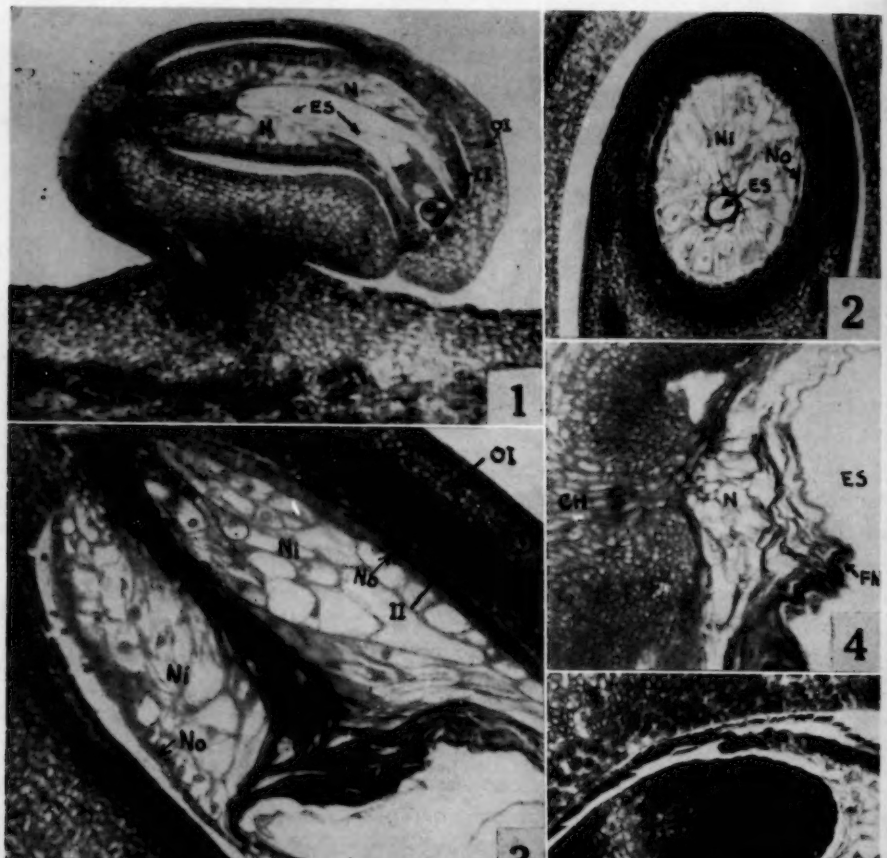
A great deal of work has been done on the structure of the embryo sac, nucellus, and endosperm in the Leguminosae. Much of this work is cited in the review of Schnarf (1928). Although different species of *Phaseolus* have served as intermittent subjects of research, no information is available on details of structure and development of the internal components of the seed of *Phaseolus lunatus*.

Materials and methods. The materials and methods used were as outlined earlier (Sterling 1954). Henderson Bush and Evergreen lima beans were the principal varieties studied in this investigation. Terminology of orientation likewise follows the definitions previously given.

Nucellus and embryo sac at anthesis. Like the inner integument (Sterling 1954) the curved nucellus is composed of two zones. At the surface is the outer zone: a single layer of thin-walled, isodiametric cells, which have rather large central vacuoles. The interior zone is composed of several layers of wedge-shaped cells, also highly vacuolate, which make up the bulk of the nucellus (fig. 1).

The admicropylar cells of the inner zone are radially elongate, and their walls are extremely tenuous. They are curved in the radial plane: inwardly toward the center of the nucellus and basally toward the chalaza. In the central longitudinal axis of the nucellus, a group of narrow, elongate, densely-staining cells extends from the posterior tip of the embryo sac to the chalazal terminus of the nucellus (fig. 1).

The embryo sac, whose main body lies at the micropylar end of the nucellus, is irregularly shaped. Its posterior tip is a tail-like extension, the length of which is about four times the breadth, in the central axis of the nucellus. The micropylar portion of the embryo sac is bulbous and is surrounded by a unicellular membranous remnant of nucellar tissue, thus being virtually in direct contact with the inner integument. The admicropylar or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anterior tip of the sac terminates as a broad beak, covered by a uniseriate layer of nucellar tissue which often appears to be disintegrating (fig. 3, Sterling 1954). This tip of the embryo sac protrudes past the inner integument and, with its nucellar cap, is enclosed solely and completely by the outer integument. Within the beaked portion occur the two large synergids and the egg cell of the megagametophyte. Lying close by this egg apparatus are the two polar nuclei, in close contact with each other. Numerous starch grains are packed among these cells and nuclei. Antipodal cells are not clearly recognizable: in several young ovules, three amorphous, deeply-staining bodies at the tip of the posterior tail-like extension of the embryo sac were taken to be the presumptive remains of the antipodals.

Post-syngamic development of the nucellus. After fertilization, growth of the embryo sac causes the immediate crushing (and disappearance) of the uniseriate cap of nucellar cells over the micropylar beak of the sac. Within a day or two, the nucellar cells situated just posterior to the broad portion of the embryo sac also begin to collapse. However, further toward the chalaza, the cells of the nucellus remain intact.

At three days, the embryo sac enlarges considerably and penetrates deeper and deeper into the nucellar tissue (fig. 3). During this growth of the embryo sac, the nucellus also enlarges. Not only do its cells enlarge, but they also undergo some divisions, so that there is an increase in the number of nucellar cells. Increase in cell size is particularly apparent adjacent to the embryo sac (figs. 2 and 3), and increase in cell number in the outer peripheral zone of the nucellus. Throughout the post-syngamic period, the axial, deeply-staining region of the nucellus (fig. 3) persists for a considerable time as a recognizable region in that senescent structure.

About the fourth day, embryo sac and nucellus begin to widen consider-

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FIGS. 1–7. FIG. 1. Ovule at time of fertilization. Micropylar end of embryo sac filled with numerous starch grains. Chalazal portion of sac extended as tail-like region into nucellus. ×122. FIG. 2. Mid-region of ovule two days after fertilization. Note radially extended interior cells of nucellus about the embryo sac. ×92. FIG. 3. Chalazal end of nucellus at three days. Although nucellus has grown by cell enlargement, embryo sac (lower right) is gradually encroaching upon the nucellar tissue. ×122. FIG. 4. A few cells of the nucellus are still recognizable at 13 days between integument at left and embryo sac at right. An extension of the chalazal integumentary bundle is visible at center left (at CH). ×92. FIG. 5. Cellular endosperm about young embryo at four days. Embryo growth is just beginning to crush the endosperm tissue adjacent to the embryonic apex. The cellular endosperm has shrunk away from the inner integument distally to the embryo. ×198. FIG. 6. Slightly larger seed at five days. Dissolution of the cellular endosperm also is apparent here. ×149. FIG. 7. Smaller seed at eight days, showing section through embryonic apex and collapse of adjacent endosperm tissue. ×149. Placenta toward base of page in all. Figure 1 of Evergreen bean; all others of Henderson Bush. Figures 1, 3–7 median longisections; figure 2 transection. CH = chalazal region of outer integument; EN = cellular endosperm; ES = embryo sac; FN = free nuclear endosperm; II = inner integument; N = nucellus; Ni = inner region of nucellus; No = outer layer of nucellus; OI = outer integument.

ably in the median plane of the ovule. By the sixth day, the embryo sac has become very large and soon occupies the major part of the intra-integumentary cavity. However at this time, the nucellus begins to decrease in size, both relatively and absolutely, as more and more of its cells, which are in contact with the growing embryo sac, collapse and disintegrate. At the chalazal region, very much enlarged cells persist despite the nucellar breakdown at the opposed end.

Further growth of the embryo sac during the ensuing week causes further, gradual collapse and crushing of the facing nucellar tissue. Some recognizable cells may be found at the chalazal end of the ovulary cavity, but between these and the embryo sac a mass of cells is compressed and disorganized by the enlarging embryo sac with its contents. At 13 days, the nucellus is reduced to a small mass of disorganized tissue at the chalaza and is almost completely obliterated (fig. 4).

Development of the endosperm. The stimulus of fertilization gives rise to extremely rapid activity in the newly-formed endosperm and embryo. Early stages in syngamy were virtually impossible to find in the materials used. It seems reasonable to suppose that this event occurs in a very short space of time. Within the first two days, a free-nuclear, parietal layer of endosperm extends along the wall of the enlarging embryo sac (fig. 5 Sterling 1954). The starch grains, which were present before fertilization, disappear; and the central region of the embryo sac is filled with a large, more or less clear, vacuole. By the third day, the number of nuclei in the endosperm has increased considerably (over 64) during the further enlargement of the embryo sac, with the majority of nuclei and most of the protoplasm about the embryo.

On the fourth day, cells are organized in the mass of endosperm protoplasm about the embryonic suspensor at the micropylar end of the embryo sac. No definite cell walls are formed during the partitioning of the protoplasm into uninuclear units, the cells being separated by protoplasmic membranes only. Very soon thereafter cellular endosperm is developed completely about the young embryo, extending over its growing apex to form a cup-shaped mass of tissue at the micropylar end of the embryo sac (fig. 5). The remainder of the endosperm extends about the wall of the embryo sac as a free-nucleate parietal layer, in which some of the nuclei are greatly enlarged (about 3–4 times the size of the nuclei enclosed in cells).

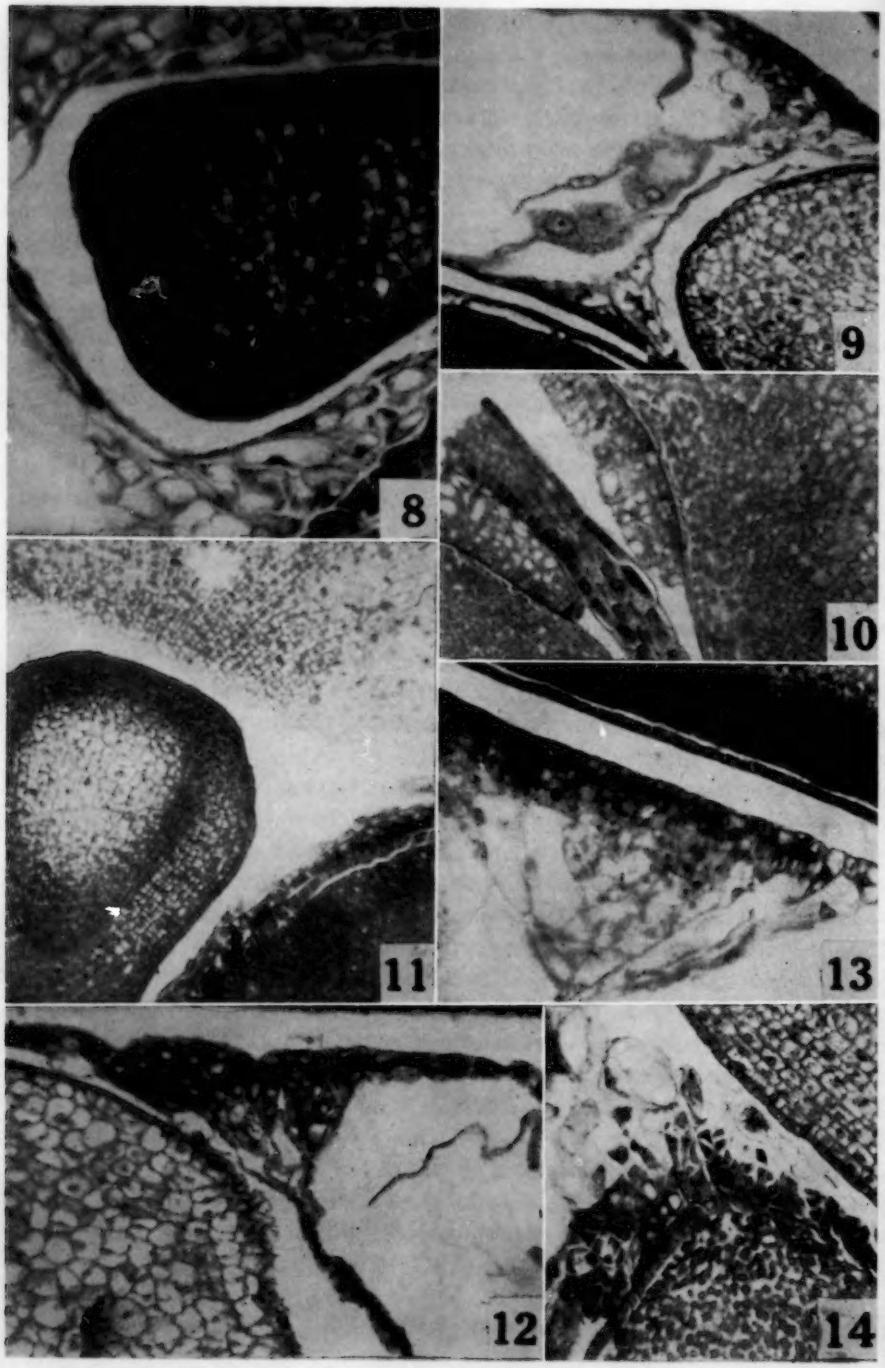
After 5–6 days, the growing embryo begins to penetrate into the thick layer of endosperm cells over its apex (figs. 6, 7). During this penetration, those cells in the path of the embryo enlarge and then break down. Thus, the layer becomes progressively thinner. However, on the sides of the embryo, the endosperm cells remain intact and, with the free-nuclear endosperm, form a continuous parietal layer about the remainder of the embryo sac.

Within ten days (figs. 8 and 9), all the endosperm cells lying in the path of the embryo collapse, leaving a thin structureless membrane which is still connected to the cellular endosperm along the embryo sac wall. The endosperm tissue at this time consists of two more or less discrete regions: (1) at the micropylar end of the embryo sac, surrounding the embryo on all sides is the cellular endosperm; (2) occupying the remainder of the embryo sac is the parietal layer of free-nuclear endosperm, which also extends across the above-mentioned membrane (fig. 9). This membrane, therefore, lying transversely across the embryo sac, is a bounding surface between the two types of endosperm tissue. The two endosperm regions enjoy a common contact along the rim of the membrane but are otherwise like separate tissues. The discreteness of the two regions is further emphasized in later growth: as the embryo elongates, the cellular endosperm no longer extends by formation of new cells from the free-nuclear endosperm, but by cell division.

At 13 days, periclinal (*i.e.*, tangential) divisions in the more or less uniseriate endosperm layer about the suspensor and the lower regions of the embryo produce radial rows of endosperm cells (fig. 10). These may be 4–5 cells in depth. Adjacent to the inner integument, these cells divide by anticlinal and oblique divisions. However, some of the innermost of the radial cell rows, in contact with the upper part of the suspensor, show signs of disintegration. The number of cells in radial rows (*i.e.*, depth of the rows) is greatest in the region from the suspensor to the level of the embryo shoot apex (fig. 11). Posteriorly, along the cotyledons to the level of the membrane separating cellular and free-nuclear endosperm, the cellular endosperm is composed of a predominantly unicellular parietal layer of very narrow, elongate cells. In the median plane, along the line of cotyledon contact, the endosperm is several cells thick. Here the cells form a band of tissue between the cotyledons. Above the cotyledons, at the rim of the bounding membrane between the two types of endosperm, the endosperm cells are again enlarged, isodiametric, and several layers wide (fig. 12).

As growth continues, the cell boundaries in the endosperm thicken noticeably and perhaps may now be called "cell-walls." Although no birefringence effect occurs with polarized light, these walls now stain green with fast green as do the cellulosic membranes of the seed coat parenchyma—indicating presumptive cellulose formation here. When the cotyledons fill the embryo sac, at the age of about three weeks, the free nuclei of the endosperm region above the cotyledons begin to disintegrate. Prior to reaching this stage, some cellular endosperm may grow out over the cotyledon tips on the dorsal side of the seed (fig. 13).

After 24 days, at which time the cellular endosperm extends throughout the entire embryo sac, further changes in that tissue are degenerative. In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the suspensor region, cells closest to the suspensor collapse first, particularly on the ventral surface of the radicle pocket. However, on the dorsal surface of the radicle pocket and at its rim, they remain more or less enlarged for some time (fig. 14). Along the remainder of the embryo sac and between the cotyledons, the originally isodiametric cells of the endosperm become darker-staining, radially compressed, and tangentially extended.

Disintegration of endosperm tissue continues throughout the next two weeks of development. Thus, by thirty days, only a thin membrane represents the cellular endosperm in most parts of the Henderson Bush seed. In the plane of cotyledon contact some cellular outline persists in the two diametrically opposed ridges of endosperm which occur here along the embryo sac wall. At the radicle pocket, one to two layers of rounded, more or less isodiametric, uninucleate endosperm cells persist, principally about the rim of the pocket and along its inner surface.

By 45 days, in the Henderson Bush bean, the only recognizable remains of the endosperm are in the radicle pocket area. In this region, the remaining endosperm cells may even enlarge somewhat. Since embryo and seed growth have ceased at this time, it is possible that these endosperm cells persist through the remainder of seed maturation. However, further stages were not studied. In Evergreen beans at 45 days, endosperm cells as such are clearly recognizable throughout the extent of the seed, with little of the radial compression which marks endosperm collapse in the Henderson Bush variety.

Discussion. In the earlier paper (Sterling 1954), the writer pointed out general familial characteristics in the structure of the seed coat of Leguminosae. Regarding details of embryo sac and nucellus construction, similar generalizations may be made. In most cases, the embryo sac is marked by the disintegration of the antipodal cells before fertilization (Young 1905, Weinstein 1926, Cooper 1933, Farley and Hutchinson 1941) or very shortly afterwards (Newman 1934, Cooper 1935, 1938; Rau 1951b). The presence of numerous starch grains likewise appears to be characteristic of the embryo

FIGS. 8–14. FIG. 8. Ten days. Last stages in breakdown of cellular endosperm at embryo apex. ×283. FIG. 9. Ten days. Separation membrane between free-nuclear endosperm (upper left) and cellular endosperm appears adjacent to cotyledon tip (lower right). Note large size of free endosperm nuclei at the separation membrane. ×122. FIG. 10. Portion of suspensor of embryo (broken in sectioning) at 13 days. Endosperm tissue surrounding suspensor has produced radial rows of cells, extending from inner integument to the suspensor. ×122. FIG. 11. Main body of embryo at 13 days, with endosperm tissue at lower right, curving next to protuberance which will enclose radicle pocket of seed coat. ×122. FIG. 12. Edge of separation membrane at 13 days. Cotyledon apex at left; free-nuclear endosperm at right. Note extensive cellular development at membrane edge (*cf.* figure 9) ×122. FIG. 13. Edge of separation membrane at 20 days. Further cellular increase has occurred at this edge. ×122. FIG. 14. Rim of radicle pocket at 22 days, showing persistent and well developed radial rows of endosperm adjacent to layer of inner integument portion of hypocotyl at upper right. ×149. Figure 8 of Evergreen bean; all others of Henderson Bush.

sac at syngamy. The occurrence of starch has been described above in lima beans and has been noted as well in *Medicago* (Cooper 1935, Farley & Hutchinson 1941), *Acacia,* and other legumes (Newman 1934).

An additional feature worthy of mention is the incipient breakdown of the nucellus at the time of megagametophyte maturity. At its micropylar end, the nucellus may disintegrate completely about the apex of the gametophyte, so that the latter is in direct contact with the inner integument. This situation has been reported in *P. vulgaris* (Meyen 1839, Brown 1917) and *Medicago* (Cooper 1935, Farley & Hutchinson 1941). Hegelmaier (1880a) described several species of *Lupinus,* in which the nucellus is completely resorbed at the time of fertilization. The same occurs in *Melilotus* according to Cooper (1933). Occasionally, as in lima bean, a layer of nucellar epidermis may remain over the apex of the gametophyte, (*P. multiflorus,* according to Guignard, 1881 and *P. vulgaris* (Weinstein 1926)). In *Acacia,* this apical layer of the nucellus is multiseriate (Guignard 1881, Newman 1934). Usually the chalazal portion of the nucellus is intact, but it undergoes some disintegration in *Melilotus* (Cooper 1933) and *Medicago* (Brink & Cooper 1947). A tail-like extension of the chalazal end of the embryo sac into the nucellus, similar to that in lima bean and *P. vulgaris* (Weinstein 1926), is figured by Meyen (1839) in *P. nanus.*

During post-syngamic development of the endosperm, the chalazal region of the nucellus is digested. However, before its breakdown, the nucellus enlarges by cell division and enlargement in lima bean, cell enlargement in *P. vulgaris* (Brown 1917), and by "secondary growth," (= cell divisions?) according to Newman (1934), in *Acacia* and some Papilionatae (Rau 1951e). The digestion of the chalazal portion of the nucellus occasionally may occur by means of a haustorial extension of the endosperm tissue (Young 1905, Rau 1950, 1951a, 1951b, 1951d, 1951e). Reports of a tapetal function of the inner integument have been made for various legumes: *Melilotus* (Young 1905) and *Vigna* (Rau 1951c); and Reeve (1948) notes that breakdown of starch-containing cells of the outer integument takes place adjacent to the endosperm of *Pisum.* No evidence of a nutritive function is to be found in the shape, size, or structure of the cells of the integuments of the lima bean.

Although not unique to the Leguminosae, another general similarity among the genera is the initial development of a free-nuclear parietal endosperm, followed by the early formation of endosperm cells about the embryo at the micropylar end of the embryo sac (Strasburger 1880, Soltwedel 1882, Meyen 1839, Hegelmaier 1885, Newman 1934, Guignard 1881, Cooper 1933, 1938). Guignard's (1881) observation of the lack of cellular endosperm in the true Vicieae has not been confirmed by other workers with the group (Cooper 1933, 1938; Hegelmaier 1880b). The disintegration of the nuclei of the free nuclear endosperm via enlargement and later breakdown, which

occurs in lima bean, has also been recorded in *Pisum*, *Lupinus*, and *Orobus* (Strasburger 1880), and in *P. vulgaris* and other genera (Soltwedel 1882). According to Decagny (1892), nuclear breakdown in *Phaseolus* is accompanied by the extrusion of large nucleolar vacuoles, which accumulate in great numbers in the embryo sac.

A feature of endosperm morphology, which may be unique to the genus, has been described in *Phaseolus vulgaris* (Decagny 1892, de Bruyne 1906), and *P. multiflorus* (Hegelmaier 1885). This consists in the virtual independence of two separate regions of the endosperm: a free-nuclear zone parietal about the embryo sac wall and over the top of the embryo; a cellular zone about the enlarging embryo; and between both zones a distinct separation layer. The same structure is present in the developing seed of lima bean. A comparative study of the young seeds of other genera might reveal the relative uniqueness of this organization.

Although the traces of endosperm tissue about the radicle pocket do not qualify the characterization of the lima bean seed as "albuminous," nevertheless it is interesting to note that cells of the endosperm can and do persist in the Papilionatae (also Corner 1951). For this reason, the statements of Schleiden and Vogel (1842), Nadelmann (1890), and Brown (1917) regarding the absence of endosperm in *Phaseolus* are not entirely correct.

From the results of the study, it is obvious that the development of nucellus and endosperm cannot serve as maturity indices for the lima bean at the stage at which it is commonly prepared for freezing or fresh eating. The optimum maturity in both Henderson Buch and Evergreen beans is reached about 35 days after flowering. However, the nucellus is completely broken down and unrecognizable as such by about 13–14 days. The endosperm persists longer, but in the Henderson Bush variety it is no longer cellular at 30 days in the main body of the seed. Moreover, the varietal variability in destruction of the endosperm would be an additional handicap in an attempt to assess maturity by the structure of this tissue.

SUMMARY

1. The micropylar end of the nucellus of the lima bean is partially disintegrated at the time of flowering.

2. After syngamy, chalazal extension of the embryo sac almost completely obliterates the remainder of the nucellus within a two week period.

3. The endosperm is parietal and free nuclear during the first few days after fertilization. It becomes cellular about the embryo early and remains cellular around this structure during further development.

4. The cellular endosperm is separated from a parietal, free nuclear,

chalazal region of endosperm by a membrane, over the cotyledons, which is formed about 10 days after fertilization.

5. The free nuclear endosperm gradually is resorbed as the embryo fills the cavity within the seed coat.

6. Although some endosperm tissue remains distinct in the radicle pocket region of the near-mature seed, the remainder of the cellular endosperm disappears during growth.

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BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 82, No. 1, pp. 50–56 JANUARY, 1955

GERMINATION OF THE SEED OF MYRIOPHYLLUM SPICATUM L.

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In conjunction with an ecological study of the life history of *Myriophyllum spicatum* L. (taxonomic treatment in Patten 1954a) in Lake Musconetcong, Netcong, New Jersey (Patten 1954b); a series of experiments was performed to determine the characteristics of seed germination. Emphasis was placed on ascertaining conditions most conducive to germination and on the effects of various habitat factors. The intention of this paper is to summarize the conclusions drawn from these tests.

Materials and Methods. Achenes were collected at Lake Musconetcong during October of 1952 and 1953 and immediately stored in tap water under refrigeration (5° C.) in the absence of light. To germinate, mericarps from these stocks were placed on filter-paper in tap water-filled Petri dishes at room temperature in diffuse daylight. Various treatments including scarifying, freezing, drying and subjection to high ion concentrations were applied prior to germinating. There were eleven experiments in all in which a wide range of these treatments and combinations of them were included and compared with untreated seeds. The results were in many instances accorded statistical analysis. Daily maximum and minimum temperatures were recorded coincident with germination in two of the tests and correlation coefficients were calculated. Bendix-Friez weather bureau-type thermometers calibrated in °F. were used.

To illustrate the character of the experiments, a brief summary of one of these with statistical work omitted is subsequently provided. Complete details of all the tests are available from the Rutgers University Library (Patten 1954b).

Experiment 11. Dates: December 15, 1953 to January 14, 1954. Purpose: To compare the germination of 1952 and 1953 achenes after their exposure to freezing, drying and absence of treatment for varying periods of time. Treatment series: A total of 8,699 mericarps were allowed to germinate, beginning December 14, after being subjected to the following treatments.

A-1 (1952) and A-2 (1953)—air-dried for three weeks.
B-1 and B-2—frozen in tap water for three weeks.
C (-1 and -2)—frozen dry for three weeks.
D—air-dried for two weeks.
E—frozen in water for two weeks.
F—frozen dry for two weeks.
G—air-dried for one week, then frozen dry for two.
H—air-dried for one week, then frozen wet for two.
I—frozen in water for one week, then air-dried for two.

J—frozen dry for one week, then air-dried for two.
K—air-dried for one week.
L—frozen in water for one week.
M—frozen dry for one week.
N—air-dried for two weeks, then frozen dry for one.
O—air-dried for two weeks, then frozen wet for one.
P—frozen in water for two weeks, then air-dried for one.
Q—frozen dry for two weeks, then air-dried for one.
R—no treatment: placed under germinating conditions directly from storage.

Results (Table I). In the experiment just outlined, an analysis of variance revealed that significant germination differences obtained both between year classes and the various treatment series. It is possible to arrange the treatments in approximate descending order of effectiveness:

1—frozen wet.
2—frozen wet, then dried.
3—dried, then frozen wet.
4—dried, then frozen dry.
5—frozen dry, then dried.
6—frozen dry.
7—air-dried only.
8—no treatment.

Frozen wet (Series B, E and L). Freezing the 1952 achenes for two weeks resulted in three times more germination than freezing for only one week, but freezing for three weeks decreased germination to only two times as much as the one week result. In the 1953 group, the greater the period of freezing the greater the resultant germination.

Frozen wet, then dried (Series I and P). In the 1952 series somewhat greater germination resulted after freezing for one week then drying for two than after freezing for two then drying for one. The 1953 seeds germinated considerably more after two weeks freezing then drying for one week.

Dried, then frozen wet (Series H and O). In the older seeds there appeared to be no substantial difference between whether dried for two weeks then frozen for one, or conversely. In the 1953 series, however, drying for two weeks then freezing for one gave considerably more germination than drying for one week then freezing for two.

Dried, then frozen dry (Series G and N). In both year classes drying for two weeks followed by a week of freezing dry produced somewhat more germination than the opposite treatment.

Frozen dry, then dried (Series J and Q). The 1952 achenes frozen dry for two weeks then air-dried for one yielded a quarter more germination than freezing dry for one then air-drying for two weeks. The opposite obtained in the 1953 series, accompanied by a complete lack of germination in Q-2.

Frozen dry (Series C, F and M). Freezing dry the 1952 series for two weeks gave greater germination than for one week, but the treatment applied for three weeks produced a slight decline of germination over the two week

result. The same was noted in the younger year class except that the decline after three weeks of the treatment was more pronounced.

Air-dried (Series A, D and K). In both year classes the treatment applied for two weeks increased germination over its application for only one week, but after three weeks of the treatment germination declined to just above the level of the one week result.

Untreated (Series R). With one exception (Q-2), the germination of both year classes of this series was considerably lower than that of the other series.

TABLE I

Summary of the number of mericarps included in each series, total percentages of germination and mean daily percentages of germination.

Series	# Achenes	Total %	Mean Daily %
B-1	349	53.02	1.7103
B-2	327	10.70	0.3452
E-1	295	73.58	2.3755
E-2	220	2.71	0.0874
L-1	300	24.34	0.7842
L-2	341	1.75	0.0565
I-1	140	34.27	1.1055
I-2	133	2.25	0.0726
P-1	201	32.35	1.0435
P-2	206	13.14	0.4239
H-1	190	21.59	0.6965
H-2	135	1.48	0.0477
O-1	187	21.36	0.6890
O-2	163	4.29	0.1384
G-1	134	14.94	0.4819
G-2	142	1.40	0.0452
N-1	202	16.38	0.5284
N-2	195	2.04	0.0658
J-1	92	9.80	0.3161
J-2	111	2.70	0.0871
Q-1	139	14.40	0.4645
Q-2	134	0.00	0.0000
C-1	185	12.42	0.4006
C-2	176	2.27	0.0732
F-1	347	14.41	0.4648
F-2	200	3.50	0.1129
M-1	279	5.75	0.1855
M-2	380	2.08	0.0671
A-1	322	11.47	0.3700
A-2	211	1.88	0.0606
D-1	400	15.25	0.4919
D-2	191	2.62	0.0845
K-1	433	10.38	0.3348
K-2	443	1.36	0.0439
R-1	307	2.95	0.0952
R-2	489	0.20	0.0065
	8699		

The results of the other experiments were similar to those just outlined. In general, the following was indicated:

1—Great variability in the capacity of individual achenes to germinate at a given time. Older seeds germinate much more readily than youthful ones.

2—Treatment of the seeds as described in the section on methods increases germination over untreated seeds of equivalent age.

3—Prolonged subjection to habitat factor treatments (freezing, drying) decreases germination compared with short exposure to such conditions.

4—A relationship was suggested to exist between germination and minimum temperature.

Discussion. Minor conflicting results were produced in some of the tests which are likely chargeable to sampling error and to errors in treatment which fell short of providing sufficient accounting of random environmental influences. Nevertheless, a general understanding of germination in this species obtains.

The experiments were not specifically designed to provide ready comprehension of the temporal pattern of germination, but the period over which they were performed (16 months) does allow for a general statement to be made. Freshly-collected seed is difficult to germinate, but good results are achieveable during the winter and spring of the first year. The general indication was that the capacity to germinate increases with age. This was illustrated in the experiment just described where there were significant differences in the germination of 1952 and 1953 mericarps. These results suggest delayed-germination and a need for after-ripening, a commonplace quality in the seeds of aquatic plants, although Guppy (1897) has pointed out that the effect is minimal in *M. spicatum:* "The fruits . . . germinated readily . . . in the year of their growth from September to December. In this respect this plant differs from most" (p. 346). Still the present tests showed conclusively that treating the seeds increased germination over untreated achenes, implying that delayed-germination is a definite character of this species.

There is a distinct germination curve which was noted time and again in the experiments. Upon transferral of mericarps from situations preventative of germination (as refrigerator storage, freezing, drying) to the more favorable circumstances under which germination was elicited, there always ensued a period of one to several days before any activity was evident. This lapse was characteristically followed by an explosion of germination after which activity gradually subsided to a level where no or only occasional germination occurred. Thus most germination is accomplished by the end of the first week and the low, intermittent-response level which follows continues unless and until there is interjected a period during which one of the treatments is applied.

Relating the laboratory results to the natural state, it is probable that mericarps deposited in the bottom sediments lie dormant for a considerable time being most prone to germinate during periods which supply favorable conditions. As to what constitutes such conditions, the evidences are only suggestive. Several significant correlation coefficients were obtained relating germination and minimum temperature. Although only a small number of the total coefficients calculated was significant, the known inhibition of germination under the conditions of storage implies that germination is restrained below a certain temperature. The magnitude of this temperature was not determinable, but it was indicated to lie between 50–65°F. It can therefore be predicted that late April or May (in Lake Musconetcong) sees an eruption of germination and that this peak of activity rapidly diminishes so that little subsequent activity occurs over the summer. The degree of such an eruption is necessarily precluded by extent of after-ripening in the individual achenes. Low winter temperatures probably represent the greatest single after-ripening factor in natural circumstances.

It is interesting to note that the factors which condition the seeds to germinate are in themselves inhibitory to germination and would be lethal to seedlings. Concerning how such adverse factors increase germinating capacity, it seems likely that the effects are mediated through the pericarps. Pericarp inhibition of germination was illustrated in a test where high germination was achieved rapidly following partial removal of the endocarp so that the testa was exposed at the micropylar end.

In nature there occur numerous situations to which the laboratory results on conditioning treatments can be paralleled. The effect of low winter temperature has already been considered. In addition, achenes are commonly frozen into the ice during this season since they lie just under the water surface through most of the autumn. These would be more prone to germinate during subsequent warming periods than unfrozen seeds. Natural scarification would obtain in stream-carried mericarps, and this would aid the downstream dispersal of the species. The conditioning effect of relatively high H-ion and OH-ion concentrations observed in one test suggests the possibility that the alimentary fluids of waterfowl would increase the germinating capacity of injested seeds.

As a protective modification against dessication of a site, the seeds excel. It is obvious from the tests that this would not eradicate the species since the dried seeds would be very responsive to reflooding. Indeed, Guppy (1897) found that "Free germination occurred in the fruits of *M. spicatum* which had been kept dry for eighteen months. . . ."

There exists the possibility that seeds dormant for a number of years will eventually after-ripen without ever being subjected to harsh environmental conditions, time accomplishing the necessary conditioning through

slower processes. Recently (April–May, 1954), considerable germination occurred in the refrigerated stock of 1952 achenes. This was contrary to all previous experience with storage of these seeds and was not noted in the 1953 series. It tends to negate the contention of a tieup between temperature and germination, at least in seeds which have attained some age; and it suggests that, under natural conditions, seeds may actually have their germination postponed until at least their second spring.

This broaches the question of the duration of viability. Guppy kept achenes under *continual* favorable germination conditions for six years during which germination occurred only through the first and second year in three groups of seed and extended into the third year in another. Thus viability would appear to be lost after three years at most. However, the present findings deem it very likely that Guppy's achenes were perfectly viable but in want of scarification or other conditioning treatment. His results do, however, tend to negate the hypothesis that time in itself is able to effect after-ripening, unless the time required be more that a half-dozen years, the length of his observations. Viability, then, possibly extends over a considerable number of years although no more precise statement is possible at this time.

It becomes obvious, in concluding, that the seed of *M. spicatum* is well-bestowed with remarkable survival adaptations mediated through its germination habit, adaptations which insure that seedlings are produced only at times when favorable conditions for ecesis prevail, and also assure that rapid germination will proceed concurrent with the inception of such conditions.

Appreciation is expressed to Drs. E. T. Moul and M. F. Buell for their criticisms and suggestions.

SUMMARY

1. Seed of *Myriophyllum spicatum* is not subject to ready germination early in its first year unless exposed to certain conditioning treatments. The necessity for a period of after-ripening is shown by the greater germinating ability of year-old seeds.

2. Treatments which were found to enhance after-ripening, in approximate decreasing order of effectiveness, are 1) partial removal of the stony endocarp, 2) scarifying, 3) freezing, 4) alternate freezing and drying, 5) drying, 6) exposure to relatively high H-ion and OH-ion concentrations and 7) prolonged exposure to low temperature.

3. The pericarps are inhibitory to germination. The conditioning treatments presumably increase germination through some action upon the pericarps.

4. There was suggested a minimum temperature below which germination does not normally occur. In nature there is postulated prompt ger-

mination when waters warm in the spring to this temperature. Cooling during the winter and possible freezing condition the seeds for such a spring eruption.

5. The mode of germination and the stimulative effect of certain habitat factors were described as having survival value, even should an adult population become decimated.

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BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 82, No. 1, pp. 57–61 JANUARY, 1955

FIBER SIZE IN *POPULUS DELTOIDES* MARSH. IN RELATION TO LEAN OF TRUNK AND POSITION IN TRUNK[1]

MARGARET KAEISER AND KENNETH D. STEWART

The dimensions of wood elements are noted for their great variability within a single species and even within the trunk of a single tree. Bergman (1949) states that the difference between the arithmetric means for fiber and vessel-segment lengths of two samples from like woods may be greater than the corresponding difference for two samples from unlike wood. The variations have been correlated with respect to the height of the elements in the trunk and their distance from the pith (Rendle and Clarke 1934a). Furthermore, there may be local variations within a sample and variations due to changes in external conditions (Rendle and Clarke 1934a).

Essentially, the purpose of this study is to establish the further relationship, or the absence of such relationship, of the variation in fiber size and the lean of the trunk. A wood study taking into account the lean of the trunk involves reaction wood, the "compression wood" of conifers and the "tension wood" of broad-leaved trees. Akins and Pillow (1950) and Terrell (1953) found in certain hardwoods that the greatest concentration and most frequent occurrence of gelatinous fibers were in samples from the upper side of branches and from the longest radii of eccentric logs. Gelatinous fibers are so called because of a loosely attached, differentially staining inner layer of the fiber walls. The extent to which this study can correlate fiber size and reaction wood, as characterized in hardwoods by gelatinous fibers, is the extent to which this type of fiber can be relied upon to appear on the upper side of the lean; often gelatinous fibers are found abundantly on the shortest radii of eccentric logs and in concentric logs (Akins and Pillow 1950). Reaction wood is associated with greater longitudinal shrinkage on drying and with inferior strength properties (Pillow and Luxford 1937, Terrell 1953). Apparently, for most species, the reaction wood of conifers is difficult to distinguish anatomically from the other wood of a tree (Sinnott 1952), and the only well established peculiarity of the reaction wood of hardwoods is the gelatinous inner layer of the fiber walls.

Materials and methods. The study has included eight samples of wood of the eastern cottonwood. These specimens were available from a series of samples taken for a study of the relationship of the lean of the trunk and

[1] The writers wish to thank Forester Richard D. Lane, Carbondale Forest Research Center of the U. S. Forest Service, for permission to use the wood specimens in this analysis.

the concentration of gelatinous fibers, a study carried out by the authors in cooperation with Carbondale Forest Research Center of the U. S. Forest Service. The samples used for the present study were taken from a cottonwood tree with a lean of 12 degrees. In each case except one the samples taken from the upper side of the lean contained a high concentration of gelatinous fibers. All samples taken from the lower side of the lean con-

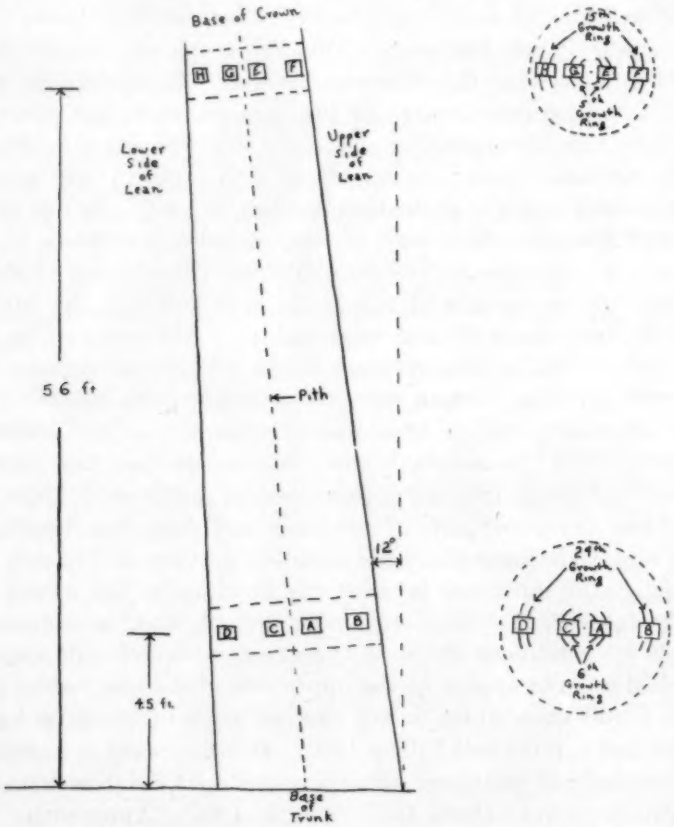

FIG. 1. Diagram to show regions and growth rings sampled from trunk of eastern cottonwood with a 12 degree lean at d.b.h.

tained a low concentration of gelatinous fibers. These particular samples were chosen because of this distribution of the gelatinous fibers. Samples were also taken from two different heights in the trunk and from different distances from the pith. The positions from which the samples were removed from the tree are shown diagrammatically in figure 1.

From each sample the length and wall thickness of 100 fibers were measured. One hundred is a number that has been suggested as being sufficient

to indicate the character of a sample (Rendle and Clarke 1943b). The means of both fiber length and fiber wall thickness were calculated. Standard deviations were calculated for the means of fiber length and wall thickness. The standard errors were calculated for the means and for the differences between the means of the samples that are compared.

There remains some question concerning whether or not the gelatinous layer of the reaction wood fibers was included in the wall thickness measurements and whether this layer affected the measurements appreciably if it was included. The limits of the gelatinous layer are difficult to determine in the macerated material from which the measurements for this study were taken. The inner wall of the fiber is obscured by the outer wall when stained and is not sharply defined in unstained material. Since no regular significant difference was found in fiber wall thickness in relation to the lean of the tree, it is possible that the layer did not much affect the wall measurements.

Each of the eight samples included in the study was a block of wood which contained a small arc of a growth ring radially complete within the block. From the lower transverse side of each block, a layer about 3 millimeters thick was removed. All wood except that of the included ring was trimmed from the removed layers and discarded. The thin slice of the growth ring was then cut into small pieces and macerated by the Schultze method (Bergman 1949). The fibers were measured from temporary slides and were not stained. The magnification used was 440. The slide was moved on the microscope stage according to a standard pattern so that no fibers appeared twice within the field.

TABLE 1

	Mean Fiber Length	Standard Deviation of Fiber Length	Mean Fiber Wall Thickness	Stand. Dev. of Wall Thickness
Sample A	.836 ± .054	.541 ± .038	.0052 ± .0005	.0049 ± .0003
Sample B	1.040 ± .066	.661 ± .047	.0047 ± .0003	.0048 ± .0003
Sample C	.760 ± .051	.514 ± .036	.0046 ± .0004	.0036 ± .0003
Sample D	1.040 ± .066	.661 ± .036	.0066 ± .0006	.0059 ± .0004
Sample E	.915 ± .064	.639 ± .045	.0045 ± .0003	.0033 ± .0002
Sample F	1.310 ± .069	.689 ± .049	.0063 ± .0006	.0060 ± .0004
Sample G	.785 ± .049	.492 ± .035	.0055 ± .0005	.0048 ± .0003
Sample H	1.240 ± .062	.621 ± .044	.0052 ± .0004	.0042 ± .0003

Results. Fiber length in the eight samples varied from .490 mm. to 1.992 mm. Fiber wall thickness varied from .002 mm. to .014 mm. The main body of the results are presented in table form. Table 1 gives the means, for each sample, of the fiber length and wall thickness. Table 1 also gives the standard deviations of the means of fiber length and wall thickness. In

addition, each of the figures in Table 1 is accompanied by its standard error value. Table 2 compares the means of fiber length and wall thickness of certain of the samples by listing the difference between the means and the standard error of this difference. In Table 2 under the column headed "Significant Difference" the word "none" is given if the value of the difference between the means is less than twice the value of the standard error. If the difference is twice or more times as great as its standard error, the quotient obtained by dividing the difference by its standard error is listed in this column. If the quotient is 2 or more, the difference is considered statistically significant. All figures are in millimeters.

TABLE 2

Comparison Between	Fiber Length	Significant Difference	Wall Thickness	Significant Difference
Samples A&B	.204 ± .085	2.4	.0003 ± .0006	none
Samples C&D	.280 ± .084	3.3	.0023 ± .0005	4.6
Samples E&F	.395 ± .094	4.2	.0018 ± .0007	2.6
Samples G&H	.455 ± .079	5.8	.0003 ± .0006	none
Samples A&C	.076 ± .074	none	.0006 ± .0006	none
Samples B&D	.000 ± .093	none	.0019 ± .0007	3.8
Samples E&G	.130 ± .081	none	.0010 ± .0006	none
Samples F&H	.070 ± .093	none	.0011 ± .0007	none
Samples A&E	.079 ± .077	none	.0007 ± .0006	none
Samples B&F	.270 ± .095	2.8	.0016 ± .0007	2.3
Samples C&G	.025 ± .071	none	.0009 ± .0006	none
Samples D&H	.200 ± .090	2.2	.0014 ± .0007	2.0

Discussion. Significantly greater mean fiber lengths are seen to occur in growth rings farther from the pith when these are compared to the mean fiber lengths of rings close to the pith and at the same height in the tree. Significantly greater mean fiber lengths are found in the outer rings from the higher point in the trunk when compared with those from the outer growth rings lower in the trunk. No significant differences were found in the mean fiber lengths between upper and lower samples when these were taken from the inner rings at both heights. No significant differences were found in mean fiber lengths that could be correlated with the lean of the tree or with the concentration of gelatinous fibers. No pattern has been

found in the variation of the means of fiber wall thickness. Since at least the lengths of the vessel-segments show a high positive correlation with fiber length (Bergman 1949) it is likely that the dimensions of other wood elements would produce the same results as fiber size.

SUMMARY

1. Fiber lengths are greater in outer than in inner growth rings at the same level of the trunk.

2. Greater fiber lengths in outer rings were noted at the higher level sampled.

3. Length of fibers shows no relationship to lean of tree trunk in the eastern cottonwood.

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BULLETIN OF THE TORREY BOTANICAL CLUB

VOL. 82, NO. 1, pp. 62–69 JANUARY, 1955

TORREYA

A YELLOW FLOWERED SILVER-ROD

JOSEPH MONACHINO

In his original publication of *Solidago bicolor* in Mantissa, 1767, Linnaeus remarked: "distincta racemis densis, floribus luteis radio alba." The white flowers of this goldenrod had been noticed somewhat earlier, for example, by Plukenet ("virga-aurea flore albo," Almagestum, 1720) and Clayton (Virga-aurea . . . floribus . . . albis," cited by Gronovius in Flora Virginica, 1739). The white "Saracens woundwort" was named *Solidago alba* by Miller in 1768. The genus, comprising about one hundred species, all American with one or few exceptions, has consistently yellow flowers. *S. bicolor* is thus an anomaly. De Candolle in Prodromus, 1836, suggested that it verges on *Aster*, and in fact the species had already been named *Aster bicolor* by Sprengel in Systema, 1826.

The white ligules and apparently yellow color of the disk florets accounts for the "bicolor" name. But are the tubular florets truly yellow? Bigelow in 1840 wrote that the disk of *S. bicolor* is yellow; Torrey and Gray in 1841, that the disk flowers are pale yellow. In more recent times, F. Schuyler Mathews in his popular Field Book of American Wild Flowers wrote that the tubular florets are cream yellow; Joseph E. Harned in his Wild Flowers of the Alleghanies explained that the white or cream colored rays of *S. bicolor* make its head two-colored. And yet anyone with access to fresh flowers of this plant, so common in our East, could prove very simply that the corollas of the disk florets are white or a diluted cream color. They merely appear pale yellow when the lobes are closed in bud, for they are translucent (likewise the loculi of the anthers) and the yellow of the pollen shows through. In age the corollas become a faded pale brown.

On September 26, 1954, the writer found in Van Cortlandt Park, near the Woodlawn Station, a single specimen of *S. bicolor* (Monachino 545, deposited in the Local Herbarium of The New Botanical Garden) with bright yellow rays and disk florets. The yellow color was definitely a goldenrod yellow, comparable to primuline yellow or perhaps wax yellow in Ridgway's Color Standards. In all other respects, leaf shape, pubescence, phyllaries, inflorescence habit, the plant was precisely like the run of the species. A week later another visit to the station and a thorough search revealed a second solitary specimen of a yellow flowered silver-rod, quite some distance away from the first find. The latter (Monachino 546) not only in the flower color but also in the roughness of its pubescence, the greenish color and the deep serration (teeth up to 3–5 mm. high) of the lower leaves contrasted with the typical silver-rods immediately surrounding it; rather it weakly suggested in these details characters of *Solidago rugosa*, a species which was abundantly represented near by. The inflorescence habit and the phyllaries conformed with the species; and both the roughness and the leaf color were matched in white flowered individuals growing a little further away.

Eight species of goldenrods are found in the Woodlawn area of Van Cortlandt Park: *S. bicolor*, *S. caesia*, *S. rugosa*, *S. canadensis* var. *scabra*, *S. juncea*, and *S. graminifolia* are abundant. *S. nemoralis* is rare, and *S. petula* is scattered around the swamp. About half a mile to a mile away from where the yellow silver-rods were collected, an additional species, *S. speciosa*, grows in moderate numbers. One unusual specimen of *S. caesia* was found near 545. This wreath goldenrod (Monachino 547), hardly wreath-like in its habit, grew to about 4 feet (12 dm.) tall; the inflorescence was amply paniculate at the summit of the stem, the heads more diffuse than is usual for *S. caesia*, the lower secondary branches of the racemoid subsecund primary inflorescence branches somewhat elongated, the floral leaves reduced, and the upper part of the plant was

more hairy than in typical *S. caesia*. The specimen suggested possible hybridization with *S. rugosa*.

In manuals the yellow-flowered *S. bicolor* keys out to *S. hispida* Muhl. The latter, according to Fernald, has the tips of the outer phyllaries usually with less contrasting green color than is seen in *S. bicolor*. Jones, Flora of Illinois, 1945, presented differences in involucre size for the two species; but this difference is not recognized by Fernald. Torrey and Gray in 1841 proposed a varietal name, *S. bicolor* β. *concolor*, for a plant with yellow ray and disks florets. According to them, this variety was not distinguishable from *S. bicolor* except in the color of the ligules. Britton, Sterns and Poggenburg in 1888 proposed *S. bicolor* var. *hispida* (Muhl.) BSP. Farwell in 1916 took up *S. bicolor* var. *concolor* and proposed four additional varieties of his own under the species. Hooker, Flora Boreali-Americana, 1840, noted regarding *S. bicolor:* "Rays of the flowers said to be nearly white; but in the Saskatchewan specimens appear to be yellow, as do some from Dr. Short (Kentucky); while others in the same collection seem to be white." Deam, Flora of Indiana, 1940, wrote he believed *S. bicolor* to be only an albino form of *S. hispida*, a fertile strain that lost its power to produce yellow rays. House, Ferns and Flowering Plants of New York State, 1924, stated that *S. hispida* is common across the state especially southward, and that it varies greatly and is often insufficiently distinct from *S. bicolor*. Tatnall, Flora of Delaware and the Eastern Shore, 1946, placed *S. hispida* in the synonymy of *S. bicolor* var. *ovalis* Farwell. A. S. Pease in 1924 reported that *S. bicolor* and *S. hispida* are locally common in Coös County, New Hampshire, and he cited a rare hybrid between the two.

H. A. Allard ("A yellow-rayed form of Solidago bicolor on Big Cobbler Mountain, Fauquier County, Virginia." Claytonia 5: 28–30. 1939; "Solidago bicolor, a puzzling assemblage in northern Virginia." Va. Jour. Sci. 2: 51–56. 1941) investigated a yellow rayed form of *S. bicolor*. He stated that the population of *S. bicolor* in some localities in northern Virginia may embrace in equal abundance yellow rayed intermingled with white rayed forms which show no other distinguishing character. Seeds of two white rayed *S. bicolor* from this assemblage were planted and the progenies revealed both white and yellow rayed forms, not differing from the bicolor type except in the flower color of the latter. Plantings from the yellow rayed progenies gave practically one hundred percent yellow. Experiments proved a genetic heterozygous condition for ray color. Allard suggsted that white was probably due to some mutational change.

Norman Taylor cites localities in Connecticut and Pennsylvania and only Copake Falls in New York for *S. hispida*, and adds that the distribution is scattered and little understood. Besides other local specimens the New York Botanical Garden herbarium has two that were collected by E. P. Bicknell in the vicinity of Van Cortlandt Park in 1892 and 1893 and distributed as *S. bicolor* var. *concolor*. Bicknell's specimens are not essentially different from those collected by the writer. Whatever the case may be with some of the collections distributed as *S. hispida*, it is certain that the two specimens studied by the writer at Woodlawn must be referred to *S. bicolor*, perhaps as a variety, form or hybrid, but not as specifically different.

There are questions which remain unanswered. What is the relationship between *S. hispida* and yellow flowered *S. bicolor*, and has the latter often entered in the identification of *S. hispida?* Are there reliable morphological differences between the two? Are there any populations or considerable stands of yellow *S. bicolor* in the local range? What is the origin of the yellow flowered silver-rod, hybridization? Reversion to some ancestral form?

New York Botanical Garden.

Field Trip Reports

October 3. Lamont Sanctuary, Palisades, N. Y. A survey of this newly acquired area (see Torreya 81: 257) was made with the purpose of formulating plans for its future usage. The midday period was devoted to a discussion of the area's features and possibilities as compared with its neighbor, the Greenbrook Sanctuary. Attendance: Rockland Audubon Society 10, Torrey Botanical Club 5. Leader, J. Harry Lehr.

October 10. Pelham Bay Park, N. Y. Eight members attended and had the pleasure of identifying the asters and goldenrods, about ten species of each, which is average for short trips in the local area. The only find in these genera deserving special mention was an *Aster*, best referred to *A. simplex*, which had violet ligules comparable in color to those of *A. laevis* growing nearby. It was with a group of white rayed individuals, essentially like it in all respects except color. The color of the fresh rays was "deep lavender" or "light lobelia violet" in Ridgway's Color Standards. On drying the rays became much darker violet. It is common to see the ligules of *A. simplex* varying from white to pale lavender, but the intense color recorded for the Pelham plant had never before been seen by the writer. Both the violet and the white rayed representatives were atypical in inflorescence habit; the peduncles were elongated and bracteated with greatly reduced leaves.

We studied three other plants which were of interest to all of us. *Bassia hyssopifolia* (voucher collected, Monachino #551) grew in the marsh area of the Eastchester Bay inlet, associated with *Suaeda linearis*, *Polygonum exsertum* and other halophytes. At the time the plant was a vivid reddish color. The fruit, enclosed in the calyx, detached easily from the plant and clung to clothes by means of the five subulate inhooked calycine spines. The species has much to suggest that it will eventually become a widely distributed weed in the East in halophytic environments. The writer was the first to collect *B. hyssopifolia* in the New York area. In September, 1936, he obtained specimens from Newton Creek, Corona and Astoria, Queens, Long Island, and sent one to Paul C. Standley, who had monographed the Chenopodiaceae for the North American Flora. Dr. Standley remarked he had no knowledge that the species had been collected previously anywhere in the East; but actually there was an earlier record, a collection from the Arnold Arboretum, reported by Palmer in the Journal of the Arnold Arboretum for 1930. Incidentally, the sea-blite (voucher #550) mentioned above had glaucous leaves; it is not understood why Fernald made a point of stating that the plant is "deep green, not glaucous." The size of the seeds and the cucullate character of the sepals prove our specimens to be *S. linearis*, not some other species. *Polygonum exsertum* is placed in the synonymy of *P. ramosissimum* by Gleason in The New Illustrated Flora, but the pedicels are described commonly longer than the calyx and the range for forma *atlanticum* is given south to Rhode Island only. In Gleason's sense our species may be *P. prolificum*, form with exserted achenes. Our plant had greatly protruding achenes, sepals margined with pink, and pedicels shorter than the calyx. *P. exsertum* (in the sense of Gray's Manual) was previously collected by the writer (#199) near Bowery Bay, Astoria, on October 13, 1936, in the locality where flourished the Astoria *Bassia hyssopifolia*.

On the woodland trail to Orchard Beach we examined *Lactuca floridana*. Taylor, in his Flora of the Vicinity of New York, gave for this species the general distribution southern New York, Pennsylvania, and south, but did not cite any locality for New York. Our plant was growing near *L. biennis*, which it resembled except for the bright white pappus. In the specimens examined the achenes had only two distinct ribs on each face; the achenes of *L. biennis* had three to five ribs (Fernald wrote "3-ribbed" for the species).

Acalypha virginica (#549) was collected alongside of the Harlem Branch of the New York-New Haven and Hartford Railroad, near the old Bartow station. Weatherby referred to this species as *A. digynoia* in Rhodora, 1927, but later he identified it as the true Linnean *A. virginica*, whereas the plant bearing the latter name in the then current manuals he called *A. rhomboidea*. Mueller Argovensis had earlier named the species *A. virginica* β *intermedia*, for it shows characters intermediate between *A. rhomboidea* and *A. gracilens*. Quite a number of plants were seen at Pelham and they were all uniform. The petioles were short, leaves lanceolate, and the bracts were deeply 12–13 acutely lobed and densely hispid. The stems in our colony were puberulent with incurved-ascending hairs; only some individuals had stems sparsely villous. The bracts often had stipitate glands, as well as villosity. The key character presented by Fernald, "stem with at least some long and spreading hairs, often villous," is not reliable, at least as far as our form of the species is concerned. Leader, Joseph Monachino.

Book Reviews

Flora of South Australia. By J. M. Black. Second edition. 1943. Government Printer, Adelaide.

John McConnell Black, the distinguished late student of the flora of South Australia, was completing the text on the Plumbaginaceae at the time of his death, in his ninety-seventh year. Part III of this work thus represents a culmination of his thirty-five years of fruitful taxonomic study of this area. It is appropriate that this installment should contain a portrait and brief biography of the author, and an interesting account of his achievements and methods of work.

The first edition of the present flora, published in four parts between 1922 and 1929 and now out of print, was one of the series of "Handbooks of the Flora and Fauna of South Australia" sponsored by the South Australian Branch of the British Science Guild (now incorporated with the British Association for Advancement of Science). The second edition is not yet complete. Part I (Cyatheaceae-Orchidaceae) was issued in 1943; Part II (Casuarinaceae-Euphorbiaceae) in 1948; Part III (Callitrichaceae-Plumbaginaceae) in 1952; and Part IV, we are promised, "will be proceeded with as expeditiously as possible." J. B. Cleland and Constance H. Eardley, of the University of Adelaide, who saw Part III through the press, have accepted responsibility for completion of the flora. They stress the fact that Black so thoroughly annotated the first edition that Part IV "when it appears, will still be his Revision, set in order but not materially altered."

The flora for which we thus owe a debt of gratitude to all three authors is actually an up-to-date illustrated manual, with keys, full but compact descriptions, distributional data, skeletal synonymy, and concise but invaluable notes on variation, nomenclature, uses, and other matters. For anyone interested in the extraordinarily rich plant world with which it deals, and for students of plant distribution, this quadripartite volume is heartily recommended.—L. Constance, University of California, Berkeley, Cal.

Drawings of British Plants. Part VII.—Leguminosae. By Stella Ross-Craig. *pl. 1–76* + index. London: G. Bell & Sons, Ltd. 5 July 1954. 12s [$1.68].

The first thing which I saw when I opened this latest part was a plate devoted to *Lupinus nootkatensis*, now naturalized in Britain; a sufficient indication that this fine series of drawings is of interest to North American botanists. Such circumboreal species as *Lathyrus maritimus* and *L. palustris* are also illustrated; and of the European legumes many have made themselves thoroughly at home in North America (species of *Medicago, Trifolium, Vicia, Lathyrus*). Each plate shows diagnostic details and is furnished with legend and a statement of flower-color. The price is a little more than 2 cents a plate.—H. W. Rickett, New York Botanical Garden.

Introductory Plant Science. By Henry T. Northen. vi + 601 pp. Ronald Press Co., N. Y. 1953.

The row of currently available texts for introductory botany on this reviewer's shelf makes rather a gay scene, with their bright colors and often interesting pictures embossed on sweat-proof cloth bindings. The contents often is depressing.

It is especially discouraging hunting through them trying to find one suitable for a one-semester course. The majority seem to have been written from the encyclopaedic angle, almost as if this were the last time that any of the students were to be exposed to things botanical and therefore that they had to be taught everyhing, even down to the last of the minutiae regarding the probable origin and supposed function of the "eye spot" in *Chlamydomonas*, and the fact that recent research has shown that a few

chloroplasts actually are to be found in the foot, seta, and capsule wall of the *Marchantia* sporophyte.

Authors of such ponderous tomes glibly tell one that their texts can "easily be adapted to a one-semester course by omitting certain parts." The simple fact is that, too often, the basic principles tend to be lost in the vast mass of detail presented. To assign such readings without adequate access to illustrative material in a heavy, year-long laboratory schedule, leads only to confusion.

Another view is that, while terms, definitions, and details are certainly necessary, as in any science, these should not intrude too greatly in a beginning course and so take precedence over basic principles in the mind of the student. Northen, in his "Introductory Plant Science," has come as close to this ideal of pedagogy as any of the many texts which this reviewer has had the painful privilege of recently examining.

Northen's text is arranged so that it can be fully utilized in a one semester course, yet it also is eminently serviceable in a full-schedule, two semester course—if the instructor is at all knowledgeable in his subject. One often wonders just what instructors using those ponderous tomes discuss in lecture, or whether they plod wearily through the same topics, giving the students the general impression that all the instructor knows—or that anybody ever can know—came out of the text. Does the advent of the encyclopaedic introductory text mean that the day of sound, well planned lectures by able teachers is coming to an end?

Northen has not skimped his subject; rather, in the opinion of this reviewer, he has made a reasonably judicious elimination of certain details not essential in a beginning course. At the same time he has given the conscientious instructor opportunity to lead the students into the by-ways of certain topics which may be particularly pertinent locally, or of immediate interest. The phraseology is neither pedantic nor pedestrian; on the other hand, the text certainly is not replete with turgid passages, too obviously designed to "create interest on the part of the student." In dealing with structure and function, Northen occasionally appears to be skating perilously close to a teleological explanation, but this probably is only a matter of occasional lapses into inept phraseology.

The illustrations are ample and, on the whole, well chosen. In a review edition some of the photographs should be retaken with more attention given to "back lighting" to avoid confusing shadows, or the retoucher's brush might be used to advantage.

Some instructors likely will wince at certain things (e.g., the implication that the terms "food manufacture" and "photosynthesis" are interchangeable, the treatment of bacteria and viruses under the heading of "Fungi," or the details in the full page illustration of the female reproductive structures of the pine), but I know of no text with a record of 100 per cent approved by specialists in the numerous fields upon which the introductory course necessarily must touch.

If any of the foregoing appears to be praising with other than faint damns let it be noted that the reviewer has adopted "Northen" for use in his own introductory course. —W. H. CAMP, University of Connecticut, Storrs, Conn.

Vegetation and Watershed Management. An Appraisal of Vegetation Management in Relation to Water Supply, Flood Control, and Soil Erosion. By E. A. Colman, with Foreword by Fairfield Osborn. xv + 412 pages + 16 plates + 6 interleaved maps (1 in color) + textfigures. The Ronald Press Company, New York. Sponsored by the Conservation Foundation. 1953. $7.00.

In many sections of the United States usable water has become, or is becoming, a scarce commodity. The urgency of increased demand on available water by a centralized and rapidly multiplying population, by expanding industry, by specialized agricultural practices, etc., has been magnified by the realization that our usable water resources have been seriously depleted. Deforestation, overgrazing, unwise agricultural procedures, wide-

spread drainage, and a multitude of other factors have contributed to this depletion. Coupled with the decline in the volume of usable water there has been an increase in unusable water. This is reflected in flood damage, severe erosion and consequent sedimentation experienced throughout the nation.

In the past few decades a number of projects have developed that have been designed to determine the effects of various watershed treatments. The literature dealing with the effects of vegetation on water production and flood, erosion, and sedimentation control has become voluminous. In August, 1951, the Conservation Foundation, realizing the need for "... a comprehensive survey of the control, by vegetative means, of water on the land, beginning at the point where precipitation strikes the foliage, and ending with the influence of [vegetation] management practices on streamflow, on channel stability, and on ground-water storage," (page viii) appointed Dr. Colman to prepare this volume. The thorough manner in which the author has accomplished his aims assures the lasting value of the book to those engaged in research, teaching, watershed management, and conservation administration.

"In the preparation of this book the interests of those primarily concerned with the less technical aspects of water conservation as well as the interests of those engaged in watershed research have been duly considered" (page xii). Fifty percent of the book is designed to acquaint the non-technician with "Water yield in the United States," "Vegetation regions of the United States," "Problems of water-yield control," and the "Principles of water-yield control." This last section discusses "The watershed and the reservoir," "Control by structural works," "Vegetation and hydrologic processes," "Control of vegetation," and control by combined "Vegetation and structural works."

An integrated review of outstanding American research on the relation of vegetation to water yield is presented in the last half of the book. "Crop lands," "Grazed lands," and "Tree-covered lands" are considered in separate chapters, as well as the effects of "Fire" and "Alternative types of vegetation." Infrequent reference is made to foreign work.

Several research projects are considered in each of these chapters. The location, objective, methods, and results of each project are related, in a very readable manner, and fitted into the general scheme of watershed managment. In each chapter, the material presented is summarized and analyzed in several concluding paragraphs.

The consummating chapter, "The opportunities and the challenge," enumerates several conclusions drawn "... from the preceding discussions, and [attempts to show] ... what lies ahead in the way of applying our knowledge to aid in the solution of water-yield problems" (page 355).

The Bibliography (pages 373–391) contains 322 references, all but ten of which are American. Many significant works are not cited, while several of those listed are of minor import. A few publications cited in the text are not included in the bibliography. —JACK MCCORMICK, Department of Conservation and General Ecology, The American Museum of Natural History, New York 24, N. Y.

Trees of Indiana. By Charles Clemon Deam, with the assistance of Thomas Edward Shaw. Fifth (Third Revised) Edition. 330 pages + 120 plates + 120 maps. State of Indiana, Department of Conservation, Division of Forestry, Publication 13A. The Bookwalter Co., Inc., Indianapolis. 1953. $3.50.

The Fifth Edition is a thorough revision of the widely useful treatise on the "Trees of Indiana." Nearly every paragraph is new or entirely rewritten; and nomenclature has been brought up to date, mostly in accordance with the Eighth Edition of Gray's Manual. The keys in nearly all groups, including the difficult oaks, hickories, plums, and cherries, have been significantly improved through intensive study of local material.

Specimens upon which the keys and descriptions are based have been deposited in the Deam Herbarium, located at Indiana University since Dr. Deam's death.

The presentation of earlier editions has been altered by deleting or drastically condensing many intimate details of distribution to permit the insertion of more than 150 new paragraphs by T. E. Shaw concerning a few of the commercial uses, insect pests, and diseases of certain species.

The total number of trees treated in the Fifth Edition is 195, 12 less than in the Fourth Edition. This number includes 167 native and 17 introduced trees, together with 11 "excluded species," reported from the State in other works without verification. These "excluded species" are discussed in their normal sequence in the text, rather than in a separate section as in previous editions. Many species reported by other authors as occurring in Indiana are not mentioned.

Several tree species which have been published as new to the State since 1941 are not included in the Fifth Edition. These, together with the number of the Indiana Plant Distribution Records[1] in which they appeared, include: X *Quercus paleolithicola* (11, 13), *X Populus jackii* (13), *Celtis tenuifolia var. georgiana* (11), *Acer rubrum f. tomentosum* (12), and *Diospyros virginiana f. pubescens* (12).

Distribution of trees by county in Indiana is shown on 120 small maps, two more than in the Fourth Edition. While most of these maps are accurate and up to date, a number of omissions are to be noted. These, together with the number of the Indiana Plant Distribution Records (Published in Proceedings of the Indiana Academy of Science, 1941–1953) in which they appeared, are: *Tsuga canadensis*, Fountain (13); *Juniperus virginiana var. crebra*, Huntington (9), Vanderburgh (2), Jackson (13), Decatur (13); *Populus grandidentata*, Daviess (7), Parke (11); *P. tremuloides*, Decatur (13); *Juglans nigra*, Bartholomew (5), Huntington (4); *Carya ovata*, Henry (13), Decatur (13); *Carya ovalis*, Crawford (13); *Ostrya virginiana*, Vermillion (6); *Fagus grandifolia*, Lake (13); *Quercus alba f. latifolia*, Crawford (11), Harrison (11), Ripley (11); X *Q. jackiana*, Allen (8), Wells (Flora); *Q. bicolor*, Randolph (5); *Q imbricaria*, Pulaski (13); X *Q. leana*, Perry (2), Posey (7), LaPorte (13), Sullivan (13); *Q. rubra*, Lake (13); *Q. palustris*, LaGrange (13), Carroll (13); *Q. schumardii*, White (12); *Q. ellipsoidalis*, Porter (13), Jasper (13); *Q. coccinea*, Starke (13), Pulaski (12); *Q. c. var. tuberculata*, Pulaski (13); *Q. falcata var. triloba*, Crawford (13); *Q. f. var. pagodaefolia*, Gibson (Flora), Vanderburgh (2), Crawford (2); *Ulmus rubra*, Carroll (6); *Ulmus americana*, Decatur (7); *Celtis occidentalis var. canina*, Parke (13), Vanderburgh (2); *C. o. var. crassifolia*, Carroll (3), Henry (12), Daviess (11), Switzerland (11); *Liriodendron tulipifera*, Ripley (11); *Asimina triloba*, Pulaski (11), Parke (11), Switzerland (11), Daviess (7); *Platanus occidentalis*, Miami (2), Switzerland (11); *Pyrus decora*, Porter (Flora); *Prunus hortulana*, Marion (13); *P. munsoniana*, Hancock (13); *P. serotina*, Whitley (2); *Gymnocladus dioica*, Fountain (13); *Gleditsia triacanthos*, Clark (8); *G. t. f. inermis*, Posey (7), Wells (6), Knox (Flora); *Robinia pseudo-acacia*, Fountain (11); *Acer negundo*, Fountain (13); *A. saccharinum*, Fountain (13); *A. nigrum f. pubescens*, Cass (3), DeKalb (3), Kosciusko (3), Miami (3), Warren (3), Howard (2), Grant (2); *Diospyros virginiana*, DeKalb (Flora); *Fraxinus americana*, Elkhart (3); *F. tomentosa*, LaPorte (14).

Several symbols used on the distribution maps have been omitted from the list of herbaria symbols on page 17. Those omitted include: H, private herbarium of Frederick J. Hermann; Hu, Huntington College, Huntington, Indiana; MC, private herbarium of Scott McCoy; and T, private herbarium of R. M. Tryon, Jr.

The number of plates has been reduced from 141 in the Fourth Edition to 120 in the Fifth, of which 19 are new. Only six of these new plates illustrate entities not shown in the Fourth Edition. Many of the plates reproduced from the earlier editions have suffered great loss of detail. Several have been enlarged from those in the Fourth Edition, but the statements of scale in their legends are unchanged. Plate 49 carries no legend; and the plates on pages 202, 309, 311, 312, 313, and 321 are unnumbered.

The treatment of the "Floral areas of Indiana," while a decided improvement over the section on "Forestal areas" in the Fourth Edition, is but a digest of the 13-year-

old section in the "Flora of Indiana" (1940). The accompanying "Map of Floral Areas" is buried nearly 300 pages to the rear of the text.

For several species, the treatment of North American distribution is incomplete, if not inaccurate. There are also several incongruities in the presentation of local distribution. For instance, "Hemlock relict areas" are indicated on the "Map of Floral Areas of Indiana" (p. 309) as occurring in several counties, including Warren and Fountain Counties. Hemlock is not recorded in Map 5 from either of these counties, although its occurrence in Fountain County was published in Indiana Plant Distribution Records, 13. The large hemlock stands in the Shades State Park are not indicated on the map of floral areas.

In regard to *Taxodium distichum*, Dr. Deam remarks that, "There is no record of its occurrence in Gibson County." However, its occurrence there is indicated on Map 6.

Literature citations are scattered in 22 footnotes and are occasionally inserted parenthetically in the text. These citations deal primarily with taxonomic and economic papers and ignore the outstanding contributions on the tree flora and forests of Indiana. —Jack McCormick, Department of Conservation and General Ecology, The American Museum of Natural History, New York 24, N. Y.

Note

The New York Times (Nov. 17) announced the death of Dr. A. F. Blakeslee on Tuesday, November 16, 1954. Dr. Blakeslee had been a member of the Club since 1916. He served several years on the editorial board, and was President of the Club in 1933. A more complete biographical sketch is to appear later.

BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 82, No. 1, pp. 70–85 JANUARY, 1955

INDEX TO AMERICAN BOTANICAL LITERATURE

COMPILED BY

LAZELLA SCHWARTEN

WITH THE COLLABORATION OF THE EDITORS OF THE TAXONOMIC INDEX

TAXONOMY, PHYLOGENY AND FLORISTICS

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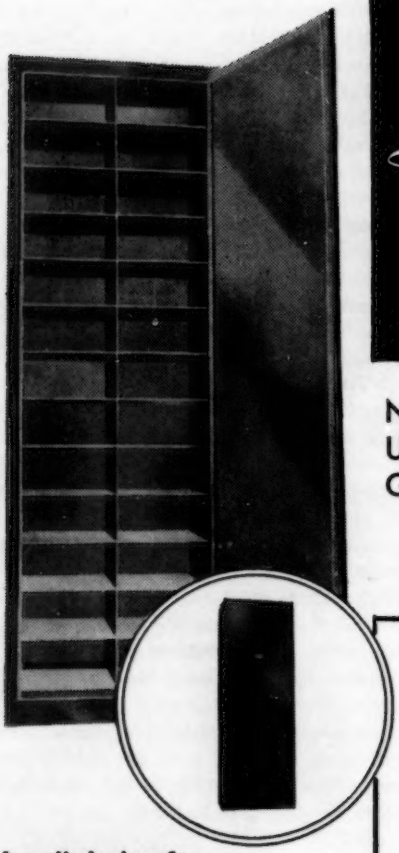

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